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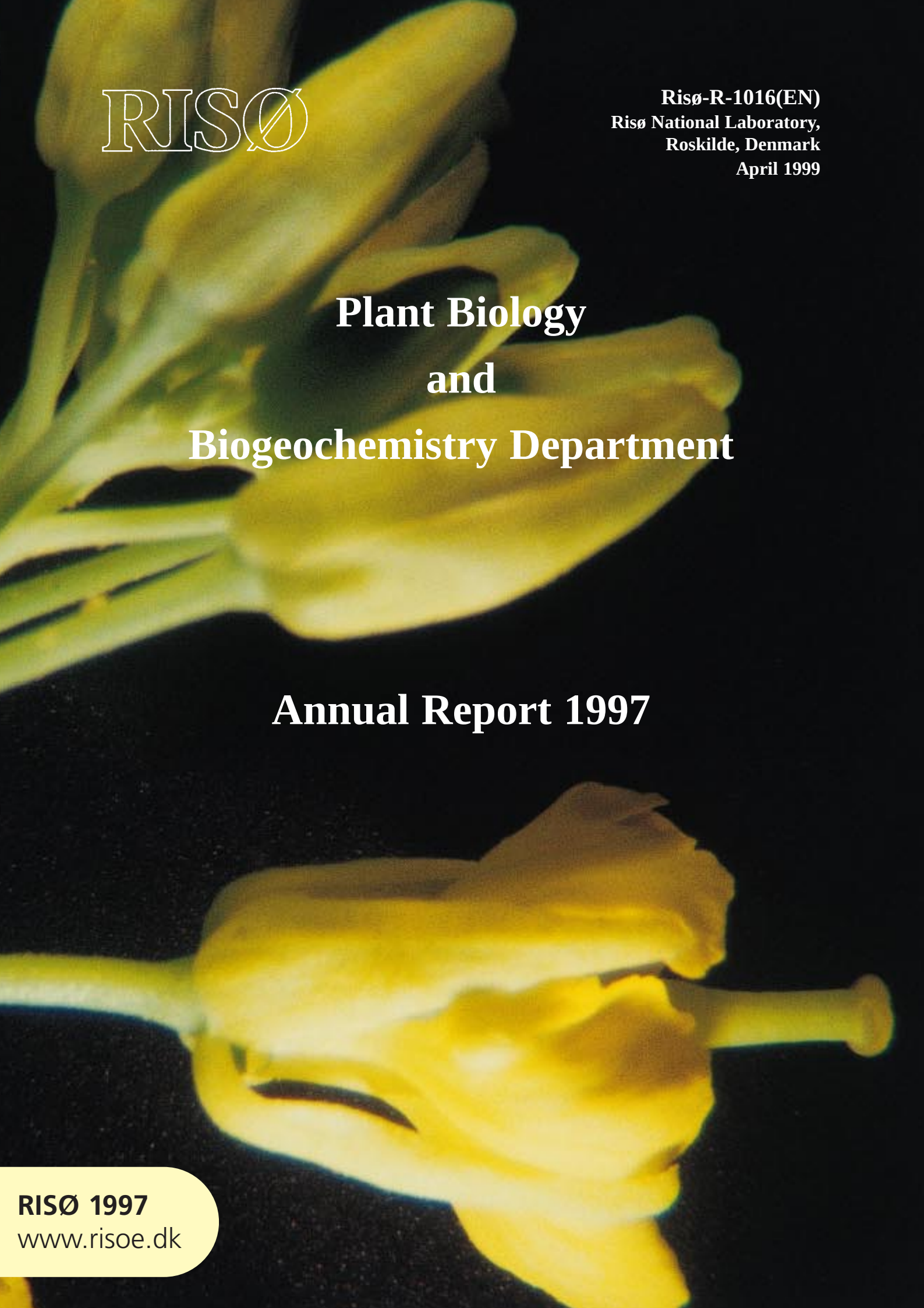

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Plant Biology and Biogeochemistry Department

Annual Report 1997

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Plant Biology
and
Biogeochemistry Department

Annual Report 1997

**Edited by A. Jensen, G. Gissel Nielsen, H. Giese,
V. Gundersen, O.J. Nielsen, H. Østergård**

Risø National Laboratory, Roskilde, Denmark
April 1999

Abstract

The purpose of the annual report from the Plant Biology and Biogeochemistry Department (previously The Environmental Science and Technology Department) is to provide a summary of our research and achievements and to give an idea of the research directions in the Department.

The Department is engaged in research to establish the scientific basis for new methods in industrial and agricultural production.Through basic and applied experimental research, the Department aspires to develop methods and technology for industrial and agricultural production, exerting less stress and strain on the environment. The research approach in the Department is mainly experimental.

Selected departmental research activities during 1997 are introduced and reviewed in seven chapters: 1. Introduction, 2. Atmospheric Chemistry and Air Pollution, 3. Resistance Biology and Plant Genetics, 4. Plant-Microbe Symbioses, 5. Plant Ecosystems and Nutrient Cycling, 6. Trace Elements and Organic Matter, 7. Dosimetry and Industrial Irradiation .

The Department's contribution to education and training are presented. Lists of publications, lectures and poster presentations at international meetings are included in the report. The names of the scientific and technical staff members, visiting scientists, Postdoctoral fellows, Ph.D. students, M.Sc. students and apprentices are also listed.

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1 Introduction

1.1 The Plant Biology and Biogeochemistry Department

Research Objectives

The Department is engaged in research to establish the scientific basis for new methods in industrial and agricultural production. Through basic and applied experimental research, the Department aspires to develop methods and technology for industrial and agricultural production, exerting less stress and strain on the environment.

Approach

The Department's expertise spans a wide range of subjects including atmospheric chemistry, chemical kinetics in the liquid and gas phase, geochemistry, geochemical modelling, hydrochemistry, analytical chemistry, process chemistry, plant molecular biology, plant pathogenicity, plant genetics, population biology, plant nutrition, nutrient cycling, ecophysiology, terrestrial ecology and ecology of trace elements.

The results of research and development are disseminated internationally to companies, institutions, organizations and public authorities through scientific publications, research reports, lectures and posters at scientific - and other professional meetings, personal communication with collaborators and through teaching courses at universities.

The research and development activities in the Department are planned for three years and reassessed every year. The research activities are mainly funded directly from the government or from National Science Research Councils. However, national and European research programmes, private foundations and commercial contracts also make substantial contributions to the total budget of the Department.

1.2 Research Programmes

1.2.1 Atmospheric Chemistry and Air Pollution

The aim of research into natural and anthropogenic influences on the atmosphere is to understand the role of the different forcing functions. An understanding of the fundamental processes is absolutely essential in building a predictive capability of these forcing functions. The complete atmospheric degradation for each individual compound must be realized in order to quantify known, as well as yet unknown, potential atmospheric environmental problems.

Research activities include basic atmospheric chemistry, gas kinetics, determination of the influence of atmospheric processes, determination of primary and secondary pollutants, transport and dispersion of air pollutants and the effect of air pollution on trees, crop plants and terrestrial ecosystems.

The environmental impact of new compounds, alternative CFCs, halon substitutes and new solvents, has been investigated in laboratory studies. Alternative fuels and fuel additives have been studied in collaboration with the Ford Motor Company. Nitronaphthalenes contribute significantly to the mutagenicity and carcinogenity of atmospheric exhaust gasses. In collaboration with the University of North Carolina gas-particle equilibria and rate constants for atmospheric reactions have been determined. It has been shown that the atmospheric fate of nitronaphthalenes can be modelled.

1.2.2 Resistance Biology and Plant Genetics

The programme intends to establish the scientific basis for breeding crop plants with new and stronger resistance to diseases and with improved nutrient efficiency. Crop plants, highly resistant to diseases and efficient in nutrient uptake, are a prerequisite for low input plant production. The research includes modelling of evolutionary processes and the detection of gene products, which are important for resistance and virulence. The host-pathogen system, barley and barley powdery mildew *Erysiphe graminis* f.sp. *hordei*, is used as a main model system for an obligate fungus.

Much of the research effort in plant biology and genetic, is devoted to identification of genetic markers for rapid and effective identification of genotypes. Understanding the regulation and expression of genes, and the characterization of gene products, is important for developing plants with improved quality of grain proteins. Transformation techniques are also implemented to improve grain quality.

Studies of plant population biology are necessary to predict possible consequences of using new genotypes possessing transgenes. Introgression of genes from crop plants to their wild relatives is being studied to assess the risks of using genetically modified plants in the plant production. Oilseed rape and wild *Brassica* species are used as model systems for these studies.

1.2.3 Plant-Microbe Symbioses

The Plant-Microbe Symbioses Programme aims to characterize genes and processes involved in the molecular interaction and compound exchange mechanisms operating during the establishment and maintenance of a symbiotic relationship between plants and microorganisms. The symbioses under study are: *Rhizobium*/pea, mycorrhiza/pea and barley and *Erysiphe graminis* f.sp. *hordei*/barley. A common feature in all plant-microbe symbioses is the integration of the micro-organism into the interior of a viable plant cell. In all plant-microbe symbioses a symbiotic interface emerges by the formation of a tissue specific plant-derived membrane. Molecular communication between the symbionts must proceed via this membrane and the interface thus constitutes the major point of control of the symbiotic relationship.

In the symbiosis between legumes and soil bacteria of the genus *Rhizobium* the micro-organism is completely enclosed by the symbiotic membrane, and the symbiotic structure constitutes a tissue specific organelle. This makes it possible for us to isolate the

membrane interface for *in vitro* studies and for physiological characterizations.

Arbuscular mycorrhizal fungi living in symbiosis with plants can be separated in a root external and a root internal part. The soil-dwelling mycelium absorbs nutrients, which are transported to the fungal strucures inside the root cortex cells where nutrients are transferred to the plant cytoplasm across the plantderived membrane surrounding the fungal arbuscule. Our main goals are to understand how the fungal nutrient uptake is influenced by environmental factors and how the subsequent fungal nutrient transport to the plant is regulated.

The disease powdery mildew of barley is caused by the ascomycete fungus *Erysiphe graminis* f.sp. *hordei (Egh)* which is an example of a parasitic symbioses. The fungus forms haustoria in the epidermal cells of barley. In order to acquire knowledge on the processes leading to the formation of the haustoria in the living cells, differentially expressed genes have been isolated.

1.2.4 Plant Ecosystems and Nutrient Cycling

The programme was established at the beginning of this year by bringing together scientists working with nutrient cycling in forests, in the atmosphere, and in agro-ecosystems. Even if the group is not yet fully integrated, it has turned out to be a fruitful combination of disciplines with considerable interaction between the projects.

The research emphasizes biological, physiological, biochemical and chemical processes involved in the transfer of plant nutrients through the Soil-Plant-Air-Continuum. The research also provides basic information about the processes involved in the turnover of carbon, nitrogen and phosphorus in agro ecosystems, helping to reduce losses of nutrients to the atmosphere, ground water or to streams and lakes.

A better understanding of the biological and chemical processes in the soil-plant-atmosphere system will lead to a reduced requirement for energy-consuming fertilizers and to a reduced loss of nutrients. The microbial biomass in the soil is of fundamental importance to the mineralization of nutrients in plant residue and animal manure. Special attention is directed towards processes involved in the cycling of nitrogen and turnover of organic matter. Nitrogen is essential for plants, but also a risk to the environment through leaching of nitrate and volatilization of some other nitrogen compounds. The study of these processes will provide the basic information needed for economical, ecological and sustainable plant production.

In order to fertilize the different parts of fields in accordance with the natural variation in topography, texture and soil fertility, we are developing systems to continuously measure plant vigour in relation to the position of the machinery in the field.

1.2.5 Trace Elements and Organic Matter

The research programme aims at understanding fundamental chemical processes and developing methods for chemical analysis of agricultural products and conversion of biomass to useful products.

The research activity in the programme has been very high, and the programme has established a large research project “Centre for Sustainable Land Use and Management of Contaminants, Carbon and Nitrogen” and obtained the intended integration with other activities in the Department. The Location of the Gamma Dating Centre and participation in the Centre for Plant Fibre Technology secure a central position for the programme in national centres.

Trace elements in the human food chain and in agricultural products are studied within the national research programme of food technology, FØTEK, and more than 60 elements in products from 200 different farmers are analysed. The programme also obtained trace element profiles of plant materials grown on different soil types, using different methods of cultivation, in collaboration with the research programmes on Resistance Biology and Plant Genetics and Plant Ecosystems and Nutrient Cycling, Risø.

The programme contributes to the scientific basis for developing the wet oxidation technique for pre-treatment and conditioning of biomass, straw and wood chips. Wet oxidation readily solubilizes lignin in straw and the product is susceptible to enzymatic treatment and fermentation. In the field of upgrading biomass, the programme aims at converting straw to ethanol by means of wet oxidation followed by fermentation.

Use of municipal sludge as fertilizer in farming raises the problem of the uptake of compounds, such as LAS and DEPH by plants. Development of analytical procedures for analysis of LAS and DEPH in sludge, soil and plants has been initiated.

The Danish R&D Centre for Decontamination of Soils and Sediment, an umbrella organization between five environmental research institutions, continued the project to develop techniques for soil and ground water remediation by bioventing and air sparging.

1.2.6 Dosimetry and Industrial Irradiation

The aim of this project is to increase the accuracy of dosimetry in industrial irradiation sterilization plants through the development of standard calibration protocols and intercomparisons. Funding for this project has been obtained from the European Commission under the Framework IV, Standards, Measurement and Testing Programme. The project is being run jointly with the National Physical Laboratory, U.K.

1.3 Research Projects

Detailed information about all research projects in the Department can be obtained from **WWW** at **http://www.risoe.dk/pbk.**

2 Atmospheric Chemistry and Air Pollution

The environmental impact of new compounds, alternative CFCs, halon substitutes and new solvents, has been investigated in laboratory studies. Alternative fuels and fuels additives have been studied in collaboration with Ford Motor Company. Nitro-naphthalenes contribute significantly to the mutagenicity and carcinogenity of atmospheric exhaust gasses. In collaboration with the University of North Carolina gas-particle equilibria and rate constants for atmospheric reactions have been determined. It has been shown that the atmospheric fate of nitro-naphthalenes can be modelled.

The atmospheric chemistry research programme has been very productive in 1997, publishing 25 papers in international scientific journals and 25 conference and book contributions. Although two new EU projects and two new Natural Science Foundation projects have been obtained in 1997, the external funding is still decreasing.

2.1 Atmospheric Chemistry of Ozone, Halogenated Compounds, Alternative Fuels and Solvents

(J. Sehested, O.J. Nielsen)

Alternative fuels and fuel additives are studied in collaboration with Ford Motor Company and The Danish Technical University. The use of oxygenated compounds in motor vehicle fuels is accelerating rapidly. In the U.S. this change in fuel composition has been pushed by the 1990 Clean Air Act Amendments. These amendments mandate the use of oxygenated fuels in areas of the U.S. which exceed the National Ambient Air Quality Standard for carbon monoxide during the winter, and in the nine worst summer smog areas. Under ideal conditions, oxygenated fuel components perform three simultaneous functions: to increase the fuel oxygen content (and thereby reduce CO emissions from carburated vehicles); to enhance the fuel octane value; and, to lower the fuel's Reid vapour pressure (RVP). The currently preferred oxygenated fuel additives, ethanol and methyl t-butyl ether (MTBE), has limitations. In particular, the use of ethanol effectively raises fuel RVP and, consequently, fuel-related evaporative emissions. For MTBE and other ethers such as ethyl t-butyl ether (ETBE) and t-amyl methyl ether (TAME), the relatively low oxygen content requires high blending volumes to meet fuel oxygen requirements. For example, to meet a 2.7 wt. % O standard requires 15.1% (by volume) MTBE in a standard fuel. Other oxygenated compounds, including organic carbonates, have been suggested as potential oxygenated fuel additives because their use can minimize these problems. For example, dimethyl-carbonate and diethylcarbonate have very high oxygen contents (53.3 wt.% and 40.6 wt. %, respectively) compared to MTBE (18.2 wt. % oxygen), and their high boiling points can lead to a reduction in the RVP of the blended fuel. The potential use of organic carbonates in motor vehicle fuels introduces a general need to map out the oxidation mechanism of oxygenated organic molecules and necessitates an understanding of the environmental impact of such compounds if they are released into the atmosphere. In 1997 the following potential fuels and model compounds have been studied: dimethylether (DEM), dimethoxymethane (DMM), dimethylcarbonate (DMC), dioxane, trioxane and 1,3-dioxolane.

The work done on solvents is part of a research programme, EUROVOC, sponsored by the EU. The work was carried out jointly with 8 European laboratories, Ford Motor Company and the National Center of Atmospheric Research (NCAR). The overall aim is to provide the scientific basis for strategies for emission control for volatile organic compounds (VOC) in Europe. In 1997 we studied HFE-7100 ($C_4F_9OCH_3$), $CF_3CH_2OCH_2CF_3$, acetone and acetaldehyde. The work on HFE-7100 was done in collaboration with Nobel-price winner, Molina.

2.2 Kinetics of the Gas Phase Reaction OH + NO + M (HONO + M and Determination of the UV Absorption Cross Section of HONO

(P. Pagsberg, E. Bjergbakke, E. Ratajczak, A. Sillesen)

Nitrous acid plays an important role as a major source of OH radicals in polluted urban areas where direct emission from automobile exhaust has been demonstrated. During the day nitrous acid is decomposed by the reaction HONO + hν → OH + NO which proceeds with a near-unity quantum yield at 368 nm. Long-path differential optical absorption spectroscopy (DOAS) has been developed for measurements of ambient concentrations of HONO, which has a characteristic vibronic structure in the range of 300-400 nm. The near-ultraviolet spectrum of HONO has been investigated in several laboratories using different source reactions for the formation of HONO. The determination of absolute absorption cross sections of HONO has been a difficult task because the photolysis and thermal decomposition of HONO give rise to products absorbing in the same spectral region, i.e. NO_2, N_2O_4 and N_2O_3. The determination of absolute concentrations of HONO has been the main problem, causing a wide scatter in the published absorption cross sections, which differ by as much as a factor of 4. In the present investigation we have employed pulse radiolysis of $NO/H_2O/SF_6$ mixtures to initiate the following reactions:

(1) F + H_2O (HF + OH
(2) OH + NO + M → HONO + M
(3) F + NO + M (FNO + M

The initial yield of F-atoms was determined by the reaction F + CH_4 → HF + CH_3 and monitoring the transient absorption of CH_3 at 216.36 nm using the recommended value of $\sigma(CH_3)$. For comparison we have also determined the yield of FNO produced in reaction (3). Kinetics of the pressure-dependent addition reaction (2) have been studied at total pressures in the range of 10 - 1000

mbar by monitoring the formation of HONO by time-resolved UV- and IR-spectroscopy. By analysis of the fall-off curve we have derived a limiting low pressure rate constant of $k_o/[SF_6] = (1.5\pm0.1)x10^{-30}$ $cm^6molecule^{-2}s^{-1}$ combined with a high pressure limit of $k_{inf} = (3.3\pm0.3)x10^{-11}$ cm^3 molecule $^{-1}s^{-1}$.

The UV-spectrum of HONO has been recorded in the range of 320-400 nm and an absolute absorption cross section of ((HONO) = $(5.02\pm0.76)x10^{-19}$ cm^2 $molecule^{-1}$ has been determined for the strongest band of HONO located at 354.2 nm. Differential absorption cross sections to be used for field measurements of HONO were also investigated.

The experimental work was carried out as a contribution to the EU-project "FORMONA" (Formation and Occurrence of Nitrous Acid in the Atmosphere).

2.3 The Liquid Phase

(K. Sehested, J. Holcman)

The influence of Transition Metal Ions, iron and manganese, on the oxidation processes in the atmospheric liquid phase was studied by stopped-flow and pulse radiolysis experiments.

The rate constants for reactions between the ferryl ions and some selected compounds of cloud water were obtained in acid solutions. In the case of inorganic compounds the reaction mechanisms proceed by electron transfer, and a good correlation between log(k) and the standard reduction potential, E^o, was obtained. The reaction mechanisms, in the case of organic compounds, are very similar to that of the OH radical e.g. H-abstraction, and a fairly good correlation between log(k) and the bond dissociation energy, BDE, was obtained. Activation parameters were measured for the reaction of FeO^{2+} with HNO_2 (E_a= 34.5 kJ/mol); Mn^{2+} (E_a= 21.3 kJ/mol); HCOOH (E_a= 22.3 kJ/mol); CH_2O (E_a= 44.5 kJ/mol) and C_6H_5OH (E_a= 28.1 kJ/mol). At higher pH, the lifetime of FeO^{2+} is substantially reduced, which is rationalized in terms of an acid-base equilibrium between the two hydrolytic forms of these species with pKa = 2.0. (Jacobsen *et al.*).

As part of the EU contract RINOXA 2, DMSO, $DMSO_2$, methansulfonic acid, methansulfinic acid and hydroxy methansulfinic acid, which are oxidation products from biogenic dimethylsulfide, were studied with respect to their oxidation by OH and NO_3 radicals and reactions with oxygen. DMSO is oxidized to methansulfinic acid and methyl radicals, which in turn react with oxygen forming methylperoxy radicals. The rate constants of OH with $DMSO_2$ and methansulfonic acid are 1.5×10^7 M^{-1} s^{-1}, whereas the rate constants with the other compounds are (6-7) $\times 10^9$ M^{-1} s^{-1}. The rate constants with NO_3 are within (6-9) $\times 10^8$ M^{-1} s^{-1} for all the compounds except 1.5×10^5 M^{-1} s^{-1} for $DMSO_2$. All the secondary radicals react with oxygen with a rate of (1-2) $\times 10^9$ M^{-1} s^{-1}.

References

Jacobsen, F., Holcman, J., Sehested, K. Reaction of the ferryl ion with some compounds found in cloud water. Int. Journ. Chem. Kinet. 30. In press.

2.4 Environmental Biogeochemistry and Atmospheric Chemistry

(T. Nielsen, A. Feilberg, C. Helweg)

2.4.1 N-PAC: Phytotoxicity and Soil Sorption

Following three projects were performed under the Danish Strategic Environmental Research Programme: 1) Fate, Plant uptake and Effects of N-PAC, an important Group of Components in Creosote and Tar (FENPAC), 2) The impact of structural properties of humic and fulvic acids on the sorption of N-PAH (azaarenes), and 3) Polar polycyclic organic matter (POM) - especially azaarenes - in contaminated soil. The projects focused on a disregarded group among the group of polycyclic aromatic compounds (PAC), the azaarenes or N-PAC, in tar and creosote contaminated soil. The amount of N-PAC is about 1-10% of the amount of polycyclic aromatic hydrocarbons (PAH). However, the water solubility of the N-PAC is 300-1000 times higher than that of PAH. Therefore, the bioavailability and transport to groundwater of N-PAC (Nielsen *et al.* 1997) may be much more important than that of PAH. Furthermore, also the most water-soluble and mobile N-PAC, e.g. quinoline, is mutagenic and carcinogenic in contrast to the PAH.

References

Nielsen, T., Bjerre, B., Gissel-Nielsen, G., Helweg, C., Binderup, M.L. (1997) Are nitrogen containing tar and creosote compounds the real contamination problem? Miljøforskning 33: 55-64 (in Danish).

2.4.2 N-PAC and N-PAH: Sorption and Water Chemistry

Mutagenic and carcinogenic N-PAC and nitrated polycyclic aromatic hydrocarbons (N-PAH) are distributed in the atmosphere between the gas and particulate phases. For the more water soluble N-PAC, the aqueous phase becomes important as well. In collaboration with the University of North Carolina at Chapel Hill (USA) the gas-particle partitioning of semi-volatile N-PAH was studied in a large outdoor smog chamber. The daytime formation from the parent PAH and the subsequent decay were also investigated and it was found that photolysis is a major degradation pathway. The atmospheric oxidation of N-PAC and nitro substituted N-PAC in the aqueous phase have also been investigated. The lifetime of N-PAC in water droplets was found to be significantly shorter than the gas phase lifetime.

2.4.3 Impact of Atmospheric Reaction Products on the Formation of Ozone

It is generally accepted that the tropospheric ozone concentration in the Northern hemisphere has increased with a factor of 2-3 in this century, meaning that the pre-industrial ozone levels were 10-15 ppb. If so, the ozone concentrations have changed from harmless levels to levels where it is phytotoxic towards many plant species. However, our determination of the non-photochemical ozone background level to be 24±6 ppb is questioning

whether the estimate of the pre-industrial ozone levels is correct. Within the Global Change Programme the Danish Natural Science Research Council has supported the project Global Changes of Tropospheric Ozone Chemistry in the North Atlantic regions (GLOCONA). The project deals with the changes of ozone. Organic nitrates affect the ozone formation by acting as a reservoir for NO_x. The participation in the European joint research project EUROTRAC-TOR will continue.

2.4.4 Chemistry of Combustion Products
(E. Larsen, H. Egsgaard)

The group has been involved in three different projects, all of them supported by the Danish Ministry of Environment and Energy. The first one "Tar cracking in low temperature gasifier for biomass" has been concluded and reported. The second project "Characterization of tar from thermal gasification of biomass" was initiated during the year and continues in 1998. The goal of the project is to characterize tar components in order to increase the knowledge of chemistry and reaction patterns of the substances formed by thermal processes and secondary down stream reactions when tar is condensed, deposited on metal surfaces or adsorbed on active surfaces.

The third project "Gas cleaning for updraft gasifier based on washing" is directly related to the experiments at the District Heating Station in Harboøre. We have participated in the experiments in Harboøre, collecting samples for analysis in the laboratory. This comprises first of all investigations of the condensed liquids analysing for stability, hydrocarbons including PAH (poly aromatic hydrocarbon) compounds and phenols.

2.4.5 Fast Method to Determine Residual Concentrations in Fish
The three-year project continues until 1999. The project is carried out in collaboration with Association of Danish Fish Processing Industry and Exporters; BioMar A/S; Danish Technological Institute; Steins Laboratory; Danish Veterinary and Food Administration; Danish Institute for Fishery, Technology and Aquaculture. At Risø the concentration of selected elements is determined. Thus, the elements Cr, Cu, Ni, As, Se, Cd, Sn, Hg and Pb have been determined in mussels.

3 Resistance Biology and Plant Genetics

In the 1997 programme our research has aimed at 1) increasing the knowedge about disease resistance in plants towards fungi in order to improve the availability of effective and durable resistance for the breeding, 2) development of molecular techniques and markers for rapid and effective identification of genotypes, 3) establishing transformation technologies in cereals to increase product quality, and 4) analysing introgression of transgenes from crops into wild relatives as part of an ecological risk assessment.

3.1 Disease Resistance and Population Dynamics of Pathogen Populations

(H. Østergård, M. Lyngkjær, B. O'Hara, L. Eriksen)

An understanding and utilization of the mechanisms of disease resistance is important for developing strategies for sustainable agriculture with reduced use of chemicals and for organic farming. Race-specific genes for disease resistance have been exploited for many years, but they have been overcome by the fungus within few years. Another type of resistance, which allows the pathogen to be established though in much reduced frequencies, is often called partial resistance. This type of resistance is presumably based on complex interactions between many genes. Partial resistance towards powdery mildew is studied in barley. In the field, barley is exposed to polycyclic attacks by the powdery mildew fungus as well as other pathogens. In collaboration with T. Carver, IGER, Wales, we have assessed the effects of a primary powdery mildew attack on the consequent accessibility (susceptibility) and inaccessibility (resistance) of attacked and neighbouring epidermal cells to subsequent infection attempts. Preliminary evidence suggests such effects could be extremely important in the expression of partial resistance to powdery mildew. In collaboration with L. Munk, The Royal Veterinary and Agricultural University, we established methods for assessing infection efficiency and spore production of another cereal disease, *Septoria tritici leaf blotch.* Sources for race-specific and partial disease resistance have been reviewed for four agronomically important diseases of barley and wheat in Denmark. For several diseases the knowledge is poor compared to the extensive knowledge about powdery mildew.

Knowledge about population dynamics of the pathogen populations is important for optimal use of resistance sources. When host resistance is not effective, fungicides have to be applied and then the risks of adaptation in the pathogen population to fungicides occur. In collaboration with senior scientist B. Nielsen, Danish Institute of Agricultural Sciences, we have investigated whether treating mildew populations with differing doses of fungicide has differing effects on the populations. To do this we kept mildew populations in a growth chamber on barley plants, treated with different doses of Fenpropimorph, and after 15 and 31 generations we took samples from the populations. Using a higher dose resulted in the population becoming more resistant than if a moderate dose was used. When examining the structures of the populations, we found that the high dose had selected a single strain of mildew, so that it dominated those populations, but not the populations treated with a moderate dose. Pathotype evenness was calculated by dividing the Simpson index of diversity by the maximum value if all pathotypes were at the same frequency. A higher value indicates a more even distribution of pathotypes. The effect of the treatments was to reduce the evenness of the pathotype distributions. Figure 3.1.1.

3.2 Molecular Markers in Barley

(A. Jahoor, J. Jensen, G. Backes)

Molecular markers are gaining their importance in the breeding of crop plants. To use these markers successfully in breeding programmes, the prerequisites are to develop a complete map with such markers. With the help of these markers, agronomically important characters, including disease resistance and quality of product can be mapped in the given genome. To establish a molecular map, a DH-population of about 200 is used originating from the cross between

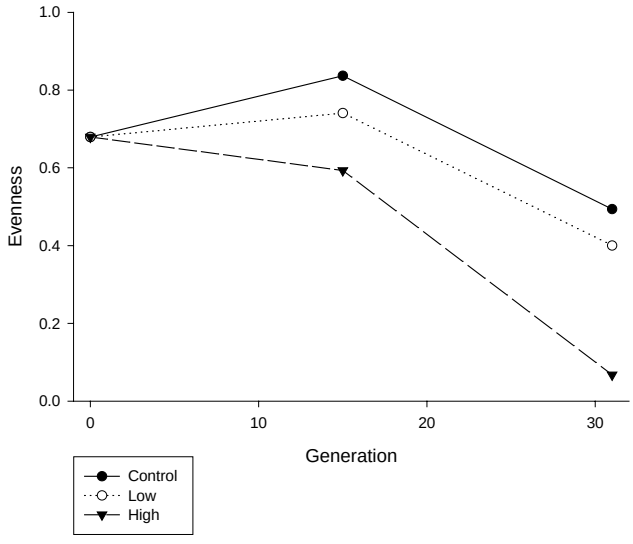

Figure 3.1.1 Evenness of frequencies of pathotypes in populations treated with different dose of fungicide.

Alexis and Regatta and developed by Danish breeders. A total of 44 RFLP markers and 22 RAPD markers have already been mapped in these populations. To obtain a dense map for this cross, AFLP markers and micro-satellites will be used in the future by the application of Automatic Sequencer and Fragment analysis (ABI 377 Prism).

Simultaneously, this population has been grown for two years in three different climatic conditions (Pajbjerg, Abed, Sejet) to obtain data from agronomically important characters such as germination, heading date, plant height and yield components. The leaf diseases such as leaf rust, necrosis and powdery mildew have scored in different environmental conditions. In addition, on fifty selected lines, different components of malting quality have also been studied and interesting results have been obtained. For further studying of malting quality, the number of progeny will be increased next year to detect loci underlying these characters. In addition to the Alexis x Regatta DH-population of spring barley, a similar DH-population has been developed of more than 200 lines from the cross between winter barley varieties, Marinka and Sonate. In this cross, a genetic linkage with 27 RFLP and 68 RAPD markers has been established. These DH-lines were also grown for two years at three locations as described above to obtain data of similar agronomically important characters. Moreover, in this population data of winter hardiness and BYM-virus resistance was also scored. Figure 3.2.1.

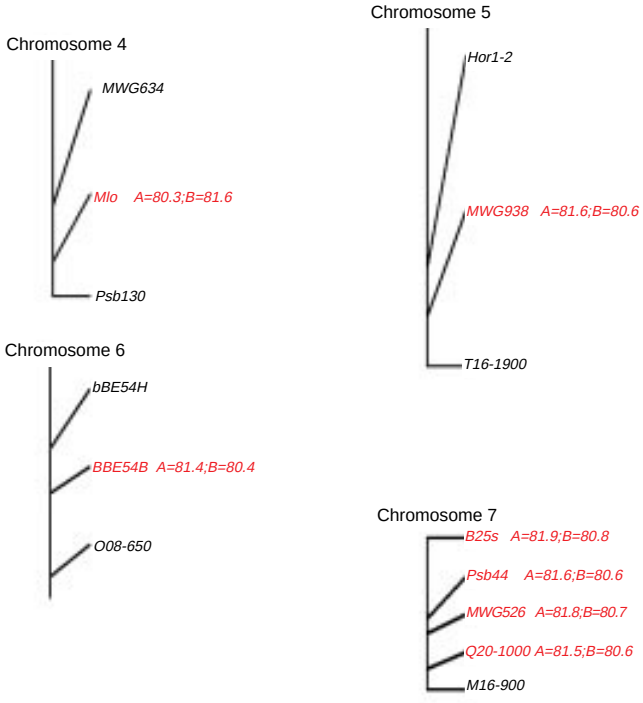

Figure 3.2.1 Association of malt extract content in DH-lines of the cross Alexis x Regatta to loci on the barley chromosomes number 4,5,6 and 7. Average malt extract percentages of DH-lines with alleles coming from A=Alexis and B=Regatta.

3.3 Barley for Better Phosphor Utilization

(S.K. Rasmussen, F. Hatzack, K.S. Johansen)

Cereal grains store phosphate in the form of phytate, a complex of hexa-phosphoinositol and minerals like Zn, Fe, Ca. Phytate accounts for 60 - 80 % of the total P and is almost indigestible for animals like pigs and poultry. The fodder is therefore supplemented with phosphate and minerals to increase the nutritional values. Through the slurry the phytase bound P contributes to an environmental pollution in regions with intensive livestock farming. In an effort to solve the nutritional as well as the environmental problems, two strategies are pursued to produce barley with more phosphate and mineral available for animal feeding. One is to find low phytate barley mutants, and the other to make transgenic barley overproduce phytase, an enzyme that will release phosphate from phytate. Seeds of the barley malting variety, Alexis, were mutagenized with sodium acid and M2 seeds, harvested from 20,000 spikes. Half-seeds were screened for high phosphate content as an indicator for low phytic acid content. At the moment mutations have been confirmed in 18 M3 seeds, using a novel TLC system to detect phytic acid and intermediates. Another approach is to produce transgenic barley with an *Aspergillus ficuum phytase*-gene under control of the barley promoter protein Z. Seed specific expressions of this fungal phytase should enhance the breakdown of phytate in the seed itself and/or during the fodder production and subsequently by animal digestion. Successful transformation and regeneration have yielded 24 transgenic barley plants in which the newly introduced phytase gene was identified by PCR. Biochemical and enzymological analyses of these plants are in progress. Other studies relate to seed specific expression of genes, useful for increasing the lysine content in barley grains or modifying the content in other amino acids. The genes involved are the bacterial feedback incentive AK- and DHPS-

genes and the barley asparagine synthase gene.

The structure function analyses of two stress-related barley peroxidases are made, including antisens blocking of the expression in transgenic barley. Finally a survey is continued of the expression patterns of three serine proteinase inhibitor serpins in vegetative tissues from barley whole-plants.

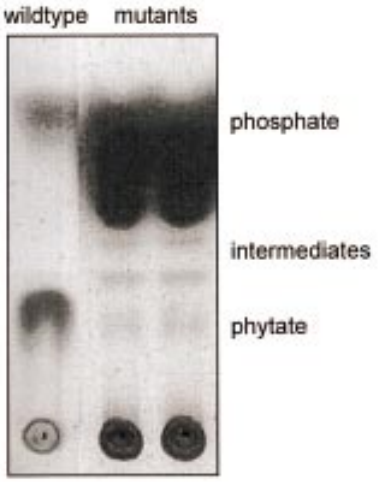

Figure 3.3.1 Thin layer chromatography of barley grain extract from low-phytate mutants and wild type "Alexis"

3.4 Risks of Growing Transgenic Plants

(R.B. Jørgensen, A. Snow)

One drawback of growing genetically engineered crops is the potential for transgenes to spread to related weeds via crop-weed hybridization. Oilseed rape, *Brassica napus*, is known to hybridize and backcross spontaneously with the weedy relative *B. rapa*. In the short term, one of the most obvious problem cases is that these weeds acquire transgenic herbicide resistance towards broad-spectrum herbicides such as glyphosate and glyphosinate and as a consequence become more abundant. However, there could be a selection against the weeds with introgressed transgenes due to growth costs associated with the transgene. We tested for costs associated with transgenic resistance to glyphosinate (BASTA) when introgressed into weedy *Brassica rapa*. Crosses were made between a commercial transgenic *B. napus* and wild *B. rapa* and the progeny was back-crossed and selected for chromosome numbers similar to *B. rapa*, resulting in a BC3 generation which segregated for herbicide resistance. We grew 457 BC3 progeny plants that segregated in a 1:1 proportion transgenic:-nontransgenic, and measured pod and seed production as well as survival and pollen fertility. There were no significant differences between transgenic and nontransgenic plants in survivorship, pollen fertility or number of seeds per plant, indicating that costs associated with the transgene were negligible. In two families, however, transgenic plants produced 20% fewer pods than nontransgenic plants. In summary, the results show that transgenic resistance to glyphosinate is capable of introgressing into populations of weedy *B. rapa* and persisting even in the absence of selection for the trait.

Figure 3.4.1 Plants after BASTA spraying (segregating for resistance to the herbicide).

4 Plant-Microbe Symbioses

The core of the Plant-Microbe Symbioses Programme is the characterization of genes and processes involved in the molecular interaction and compound exchange mechanisms operating during the establishment and maintenance of a symbiotic relationship between plants and micro-organisms. The symbioses under study are: *Rhizobium*/pea, mycorrhiza/pea and barley and *Erysiphe graminis* f.sp. *hordei*/barley.

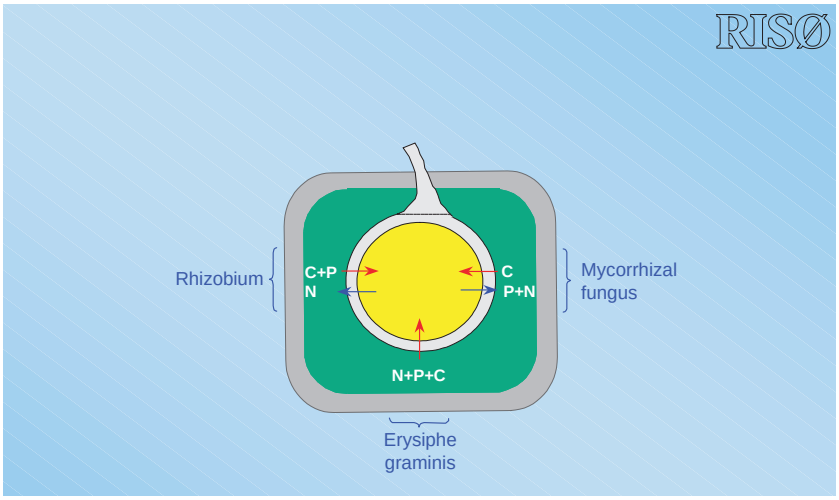

Figure 4.1 The exchange of nutrients is studied in the symbioses between Rhizobium, mycorrhizal fungi and Erysiphe graminis and their respective plant partners.

A feature common to all plant-microbe symbioses is the integration of the micro-organism into the interior of a viable plant cell. In all plant-microbe symbioses a symbiotic interface emerges by formation of a tissue specific plant-derived membrane. Molecular communication between the symbionts must proceed via this membrane and the interface thus constitutes the major point of control of the symbiotic relationship.

4.1 The Exchange of Compound between Rhizobium and Pea is Studied in Isolated Symbiosomes

(L. Rosendahl, A.C.W. Simonsen)

In the symbiosis between legumes and soil bacteria of the genus *Rhizobium* the micro-organism is completely enclosed by the symbiotic membrane and the symbiotic structure constitutes a tissue specific organelle. This makes it possible for us to isolate the membrane interface for *in vitro* studies and for physiological characterizations. We have identified and characterized a transporter for ammonium in the plant-derived membrane. The transporter is voltage gated and directed so it may facilitate export of fixed nitrogen from the bacteria to the plant.

The biochemical processes in the interface are mediated by a range of proteins some of which are symbiosis specific. We have demonstrated that the majority of *de novo* synthesized proteins in the interface are of plant origin. This implies that the regulation of the symbiotic relation is primarily controlled by the plant.

4.2 Mesh-Enclosed Compartments Containing Tracer Isotopes are Used to Study the P Transport in the Symbioses between Mycorrhizal Fungi and Plants

(I. Jakobsen, M. Gravito, P. Schweiger, T. Mikkelsen, S. Ravnskov)

Arbuscular mycorrhizal fungi living in mutualistic associations with plants can be separated in a root external and a root internal phase. The soil-dwelling mycelium absorbs nutrients, which are transported to the fungal structures inside the root cortex cells where nutrients are transferred to the plant cytoplasm across the plant-derived membrane surrounding the fungal arbuscule. Our main goals are to understand how the fungal nutrient uptake is influenced by environmental factors and how the subsequent fungal nutrient transport to the plant is regulated.

A method has been developed for the measurement of phosphate transport by native mycorrhizal fungi in the field. The method is based on mesh-enclosed compartments containing soil, which has been labelled with tracer isotopes and which can be accessed by hyphae but not by roots; hyphal nutrient transport is measured as the amount of tracer present in the plant. An evaluation of the method in a pot experiment showed that non-hyphal transport of ^{32}P-phosphate out of the compartments was insignificant when the labelled soil volume in the root free compartment was surrounded by a buffer layer of unlabelled soil. The method has been applied successfully in the field to demonstrate that mycorrhizal fungi can transport significant amounts of phosphate to winter wheat grown in an organic crop rotation at soil phosphate levels only slightly below Danish average. The fungal uptake of phosphate from the labelled soil in root free compartments was four fold the estimated uptake from corresponding soil volumes with both roots and hyphae. Although the absolute contribution of mycorrhizal fungi to the overall phosphate uptake by the wheat crop cannot be deduced from this work, it represents the first direct documentation of phosphate transport by native mycorrhizal fungi under field conditions.

Root-free compartments are also used to study the influence of soil phosphate, pesticides, organic substrates and saprophytic soil micro-organisms on phosphate transport by mycorrhizal fungi. The potential phosphate transport was similar in two populations of fungi exposed to different soil P levels in a

long-term fertilizer experiment. This suggests that future reductions in soil P levels of cultivated soils can be implemented without any undesirable effect on the function of mycorrhizas which become of increasing importance under those circumstances. Certain fungicides were found to be detrimental to fungal phosphate transport, which was also reduced by a supply of starch and cellulose to the soil. The effect of these simple polysaccharides coincided with and was probably the result of a reduced growth of the root-external phase of the fungus. In contrast, fungal growth was enhanced by the more complex substrates, dry yeast and bovine serum albumin. The phosphate transport by the mycorrhizal fungi appears to be relatively insensitive to the presence of a number of different saprophytic fungi and bacteria.

Elevated CO_2 levels and soil temperatures are components of climate change and their effects on root growth and root turnover are studied in the Risø Environmental Risk Assessment Facility (RERAF). Experiments have been carried out at two levels of soil nitrogen and in the presence or absence of mycorrhizas. The soil temperature was controlled by means of modified freezers and transparent root observation tubes were inserted diagonally into the pots. The time course of appearance and later disappearance of roots, in a large number of squares of a permanent grid on the wall of the observation tubes, was monitored by a modified video camera inserted into the tubes. Rates of root production and mortality are currently being derived from computer analysis of digitalized video images.

4.3 Molecular Biology is Used to Characterize the Erysiphe graminis f. sp. hordei Genome and to Isolate Differentially Expressed Genes

(H. Giese, S.K. Christiansen, C. Pedersen, P. Mouritzen, M. Grell, B. Wu)

The disease powdery mildew of barley is caused by the ascomycete fungus *Erysiphe graminis* f.sp. *hordei (Egh)* which is an example of a parasitic symbioses. The fungus forms haustoria in the epidermal cells of barley. In order to acquire knowledge on the processes leading to the formation of the haustoria in the living cells, genes which are differentially expressed have been isolated. Two of these have been expressed in *E. coli* and we have in collaboration with DTU produced antibodies to facilitate cellular localization of their products. We have established the differential display technology to identify genes, which are specifically expressed when the fungus penetrates the epidermis and when the haustoria are developed. We have identified 15 sequences, which are differentially expressed, some have known function, and others represent novel genes. Transformation of *Egh* has been achieved using constructs containing the GUS reporter gene. Green Fluorescent Protein offers the possibility to study gene expression in living tissue. Several transformation vectors containing the GFP reporter gene has been constructed and we have shown the expression of GFP in *Egh* conidia. This is the first step in the development of a stable transformation system, which allows *in vivo* assay of the expression of cloned genes in *Egh*. Two new *Egh* crosses have been made and one cross is now being mapped using RFLP and AFLP markers. The AFLP technique is working well in *Egh* and gives a lot of polymorphism. In collaboration with Carlsberg a cDNA library of *Egh* is being sequenced, the ESTs are being used as RFLPs to provide single copy markers, which can be used as landmarks on the *Egh* genome. Three avirulence genes are found to be very closely linked.

5 Plant Ecosystems and Nutrient Cycling

The program was established at the beginning of this year by bringing together scientists working with nutrient cycling in forests, the atmosphere, and in agro ecosystems. Even if we are not yet fully integrated, it has turned out to be a fruitful combination of disciplines with considerable interaction between the project groups.

5.1 Mineralization-Immobilization Turnover

(E.S. Jensen, P. Ambus)

Major emphasis of our research is on the mineralizsation-immobilization turnover (MIT) and plant uptake of N after applying crop residues and animal manure to soils, the production of trace gases and on symbiotic N_2 fixation by legumes. The aim is to improve the understanding of N-cycle processes of agro-ecosystems in order to better match the supply of N to crop requirements and minimize the environmentally unacceptable losses from soil to the wider environment. The research is based on ^{15}N and ^{13}C-methods for studying processes of N and C-transformation.

The mixing of crop residues with different chemical characteristics may result in a decomposition and net N mineralization, which differ from the decomposition and net N mineralization predicted from the turnover of each component of the mixture alone. We studied the mixing of barley, clover and ryegrass materials and found that mixing residues caused patterns of respiration and net mineralization, which differed from the predicted, due to *e.g.* high N residues contributing N to the microbial population, which then may be able to decompose the low N residue under conditions, where soil mineral N is limiting decomposition.

5.2 N-Turnover in Low-Imput Agro-Ecosystems

(E.S. Jensen, F.V. Jørgensen)

Symbiotic nitrogen fixation by legumes is an important N-source in low input sustainable agriculture, such as organic farming systems. When symbiotic N_2 fixation in white clover is estimated using ^{15}N-isotope dilution harvesting leaves only, the amount of N_2 fixed in below cutting height tissue is ignored. Therefore, experiments have been carried out to estimate the ratio between N accumulation in leaves versus N accumulation in stolons + roots. It was found that N accumulated in stolons + roots were approximately 70% of the N accumulated in leaves. Using this relationship the total amount of N_2 fixed in white clover can be estimated by harvesting leaves only and use the expression: Total amount of N_2 fixed = Amount of N_2 fixed in leaves x 1.7. The importance of the below cutting height tissue in the turnover of N in the grass/clover pasture is currently being investigated.

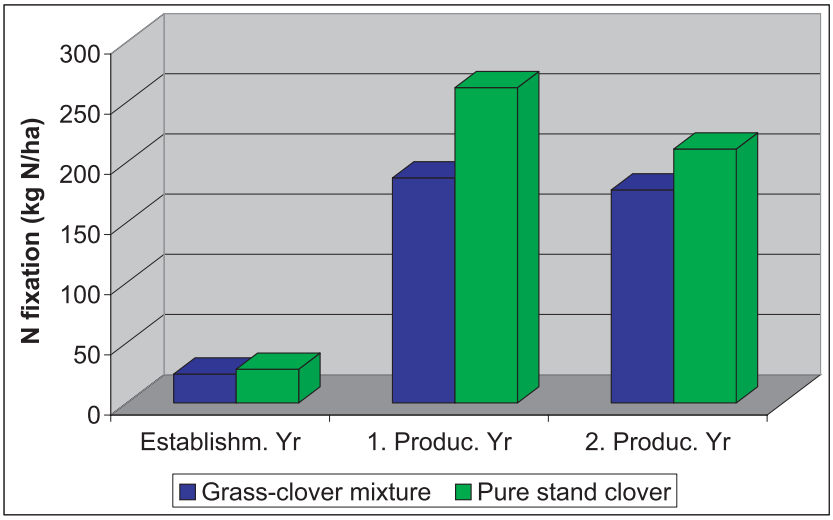

Figure 5.2.1 N_2 fixation in white clover in pure stand or in mixture with perennial ryegrass.

5.3 CLIMEX

(C. Beier, L. Rasmussen)

The CLIMEX project is linked to the global climate change problem and involves manipulation of the temperature and the atmospheric CO_2 concentrations in an open forest ecosystem in Southern Norway. The manipulations are conducted by means of a large greenhouse. The overall results of the experiment have shown that the increased temperature in the treatment plots has increased the decomposition of the organic material. Consequently, nitrogen availability and nitrogen runoff have increased.

5.4 NORN

(C. Beier)

The NORN project aims at modelling the C and N circulation in two Norway spruce forests in Denmark and Sweden by the SOILN model. In 1997 Risø has parameterized and tested the model on 10 years of existing data on climate, C and N pools in the ecosystem and soil solution concentrations in a spruce stand at Klosterhede, Western Jutland.

The main work was concentrated on the model description of the microbial part in order to obtain sufficient N supply to the plants and at the same time having realistic changes in the C and N pools in the soil according to measured values and considerations.

5.5 EUROFLUX

(T. Mikkelsen, C. Beier, K. Pilegaard, L. Rasmussen)

In the frame of the Danish Strategic Environmental Research programme

a new project on the effects of land use and organic waste application on carbon and nitrogen fluxes has been launched in the autumn 1997. The project involves partners from different research groups at Risø and other research institutes in Denmark. The aim of the project is to quantify and compare the fluxes of gaseous and water mediated fluxes of carbon and nitrogen compounds in forest and agro-ecosystems with and without sewage sludge application. The field site is located in a beech forest with surrounding agricultural fields near Sorø. The site is also used by the EU project EUROFLUX. During the last three months of 1997 sampling equipment has been installed at the site, so measurements can start from the beginning of 1998.

5.6 Biosphere-Atmosphere Exchange
(K. Pilegaard, T. Mikkelsen)

The research on biosphere-atmosphere exchange is focused on the exchange of O_3, NO, NO_2, CO_2, water vapour and particles. The work is mainly carried out at two forest experimental stations (Ulborg Plantation in Western Jutland and Lille Bøgeskov on Zealand) and at urban sites (particles). The work is carried out in close collaboration with the programme Atmospheric Transport and Exchange in the Wind Energy and Atmospheric Physics Department, Risø, and with the Botanical Institute, University of Copenhagen.

5.7 Field Campaigns
(C. Beier, T. Mikkelsen, K. Pilegaard)

During 1997 we have participated in a number of field campaigns in connection with projects under the Danish Environmental Research Programme, Danish Forest and Nature Agency, and the EU projects EUROFLUX, FOREXNOX and BEMA (Biogenic Emissions in Mediterranean Area) experiment in Spain.

5.8 Airborne Pollutants from Roads
(K. Pilegaard, P. Fauser)

During a project dealing with the fate of particles from asphalt and tire-tread new chemical methods have been developed to identify the sources. Application of these methods on plant and soil material has given new information of the spread of particles along roads and the uptake in plants as source of pollution.

5.9 Effects of POM on Plants
(G. Gissel-Nielsen)

A study of the effects of POM on plants showed a lethal effect of small amounts of acridine on some plants, especially dicots, and especially on the sprouting of the seed and on the young plants. A less drastically effect was observed when quinoline was added to the soil.

5.10 Genetically Background for Plant Nutrition
(K. Engvild, G. Gissel-Nielsen)

In the summer of 1997 a grant for the project on “Application of molecular biology to identify and isolate genes important for P-use efficiency in barley” was awarded to the programme. This project will run from 1997-2001.

6 Trace Elements and Organic Matter

The research activity in the programme Trace Elements and Organic Matter has been very high and external funding has been very good. The programme has obtained the intended integration with the other activities in the department in connection with the establishment and our administration of the Centre for Sustainable Land Use and Management of Contaminants, Carbon and Nitrogen. Location of the Gamma Dating Centre and participation in the Centre for Plant Fibre Technology secure a central position for the program in national centres. Within the area of trace elements and organic micro pollutant in the food chain, we have developed very promising analytical methods for LAS (linear alkyl benzene sulfonates) and very interesting results concerning the significance of production methods for trace element profiles in gardening produce.

6.1 Trace Elements in Agricultural and Gardening Produce

(V. Gundersen, A. Bibak, S. Stürup)

For many years it has been discussed if there are any differences in the content of trace elements between agricultural and gardening produce farmed by different cultivation practices. Investigations already performed have shown no difference in the rather few elements investigated, but the research has not been very extensive and has only been related to samples from market baskets, where the origin and the way of producing are not well documented. The lack of analytical methods for multi element analysis of elements in extreme low concentrations has probably been responsible for the very limited investigations, but with the new HR-ICPMS instrument and the clean room facilities we have in the programme, we have been able to study the problem in more detail.

In the project in the Danish FØTEK programme we investigate the concentration profile of about 65 elements with special attention to elements which appear in extreme low concentrations, in different agricultural and gardening produce farmed by different cultivation practices. Special attention was paid to avoid contamination in the sampling procedure and in the sample preparation. Each farm was described in relation to the farming procedure the last five years and the location in connection to cities, main roads, motorways and industries.

6.2 Organic Contaminants in Soil-Plant Systems

(C. Grøn, F. Laturnus)

In the industrialized countries, man-made chemicals are found widespread in terrestrial and aquatic ecosystems. The major sources of anthropogenics to soils are spills, pesticide application, atmospheric deposition and organic waste application. In agro-ecosystems, such anthropogenic compounds are of particular concern because they can be transferred to humans via agricultural products or leaching to groundwater. Also, their occurrence may affect the soil ecosystem leading to reduced soil fertility and agricultural productivity. In urban areas, contaminated soils may furthermore impact the indoor air quality in buildings, as well as the health of construction workers. Research on the mobility, fate and bioavailability of organics in soils is therefore essential to provide the basis for safe and cost efficient management of organic contaminants in soils.

6.2.1 Measuring Organic Contaminants in Plants

The occurrence of organic contaminants, in particular pesticides, in crops is routinely monitored as part of the food inspection. In investigations on plant uptake of organic contaminants, methods for determining new compounds with low limits of detection are called upon. In 1997, a method has been developed enabling chemical analysis for linear alkyl benzene sulfonates (LAS, anionic surfactants) in plant material, such as barley shoots. The method includes several steps of extraction, extract purification and concentration, and ends up with quantification using HPLC with fluorescence detection.

6.2.2 Organic Contaminants and Recycling of Organic Wastes in Sustainable Agriculture

Recycling of nutrients and organic matter from organic wastes to agricultural lands is essential in reducing the need for fertilization and maintaining the soil quality with respect to organic matter content. An integral part of developing sustainable agricultural production methods is, therefore, recycling of organic wastes. With the recent findings of anthropogenic compounds in high concentrations in waste products such as sewage sludge and compost, it has become essential to reduce contaminant levels and to assess the risks associated with the contaminants introduced in the agro-ecosystem.

Therefore, an open centre on the management of anthropogenic compounds, carbon and nitrogen in sustainable land use has been established, headed at Risø and with financial support from the Danish Environmental Research Programme 1997-2000. The centre covers monitoring for contaminants (antibiotics) in wastes, bio-processing of wastes, the fate and effects of residual anthropogenic compounds in agricultural ecosystems, risk assessment for the anthropogenic contaminants in agricultural soils, as well as determination af the carbon and nitrogen fluxes in agricultural and natural systems. Behind the centre is an interdisciplinary group of qualified scientists from 12 different research institutions and universities. The centre research has been initiated during the second half of 1997 and will include extensive studies of plant uptake and metabolization of organic contaminants at Risø.

6.2.3 Mobility of Organic Contaminants from Soils Contaminated with Petroleum Hydrocarbons

Sites contaminated with petroleum hydrocarbons from leaking underground storage tanks and spills are found all over Europe, and a major effort is currently devoted to clean up of these sites. In Denmark alone, more than 100 mill. DKr. are spent yearly by the petroleum industry on remediation of gasoline sites. In most cases, off site land farming/biopile treatment or in situ bioremediation are the remediation techniques of choice. Still, a major draw back of these technologies is their failure to comply with regulatory limits for clean soil. Because the residual contaminants are less volatile, less available for biodegradation and perhaps also more recalcitrant than the original contaminants, the last phase of contaminant elimination from the low residual level to the regulatory limits becomes slow and costly.

In order to attain realistic, but also environmentally safe end points of remediation for use in site closure or clean soil decisions, research has been initiated at Risø to establish methods for determining the mobility (volatility and leacheability) of residual contaminants. The research is part of a "centre contract" between 5 Danish research institutions, including Risø, 2 development companies, 1 consultant firm and the Danish petroleum industry on bioremediation of contaminated soils: Centre for In Situ Remediation of Soil and Groundwater by Ventilation, CEVENT. The CEVENT centre is headed by the Water Quality Institute and funded by the Danish Ministry of Industry.

6.3 Trace Metals in the Geosphere

(H. Kunzendorf)

During 1997, focus was on two activities: work within the EU MAST3 project BASYS and the first full-year routine operation of the national lead-210 Gamma Dating Centre (GDC), serving 5 Danish institutions.

Most of the surface sediment cores recovered from the North Central Basin of the Baltic Sea in 1996 were dated and the semiquantitative analytical screening tool (EDX analysis) was tested. Some of the short cores were already analysed. A clear chemical marker was observed at the redox boundary, at about 5 cm depth in the cores, showing a pronounced manganese and iron anomaly. Apparently, manganese and iron are remobilized in the sediments at depth and from the upwards migrating solutions Ca and/or Mn containing carbonates are re-precipitated at the boundary. Use of such chemical profiles also gives information on whether coring has been carried out properly. This means that for instance, lack of a manganese carbonate horizon may flag loss of top sediment material. The final sampling operation in the 3 chosen basins of the Baltic Sea (Bornholm Basin, Gotland Basin, and North Central Basin) was conducted with R/V Kottsov in early July 1997. During the cruise with participation of all project partners, 3 long (> 5 m) and 8 surface sediment cores were recovered.

Work within GDC included dating of cores recovered for mainly centre partners but through the partners, a number of cores from other Nordic research institutions was also included in the dating routine. Work within the EU MAST3 ENAM project with subcontractor status (co-operation with GEUS) was continued and dating results were presented at a meeting in Germany.

6.4 Recycling of Agricultural and Industrial Waste

(A.B. Bjerre, A.S. Smidt, A. Woidemann, A. Plöger)

For many years land-filling and incineration has been the only way to deal with waste derived from human activities. However, waste streams derived from both agricultural and industrial processes can be considered as raw material for the production of valuable products. This consideration has created new research areas and the development of new promising technologies. One example is the utilization of lignocellulose based material. Lignocellulose is the pseudonym for all kinds of plant cell wall materials such as wheat straw, wood fibres, and grasses but also waste paper, which can not be reused in the paper industry. Lignocellulose has the advantage of being a CO_2 neutral material giving a more sustainable and environmental friendly plant production. At Risø National Laboratory new techniques (wet oxidation and steam explosion) have been investigated for the fractionation of lignocellulose to its three constituents: cellulose, hemicellulose and lignin. One promising application is the conversion of wheat straw to available polysaccharides by wet oxidation, which was followed by fermentation to high-value products. At the high temperature and pressure used in the process, lignin is solubilized and utilized directly as fuels (leading to energy saved) with a simultaneous production of low weight carboxylic acids and hydroxylated phenol derivatives *e.g.* vanillin. These are all valuable products in many industrial processes *e.g.* production of dyes, food ingredients, pharmaceuticals etc. However, the most interesting about the process is the fact that no inhibitory compounds for ethanol producing bacteria and yeast are formed during wet oxidation, where most other pre-treatment processes produce inhibitors for following fermentation. Therefore, wet oxidation is a very promising alternative to the conventional processes such as steam explosion and steaming.

Lignocelllulose is also a potential fibre material for new environmentally friendly materials and products. One such implementation is the reinforcement by pre-treated cellulose fibres in plastic composites. Cellulose is characterized by having a high tensile strength over weight ratio and is a good alternative to glass and carbon fibres. Risø is part of the virtual Centre for Plant technology together with RVAU, DTU, DIPSS and Novo Nordic. The aim of this centre is to promote the use of lignocellulosic fibres for industrial applications.

The tar-containing wastewater deriving from the gas pyrolysis of straw and wood chips, damages/kills

conventional biological treatment plants. Treatment by wet oxidation for 30 minutes detoxify this wastewater evaluated biologically by *Nitrosomonas* and *Nitrobacter* as well as by the inherent biodegradability test, the modified Zahn-Wellens test. Wet oxidation of the tar-model compound, quinolin, was extensively studied to evaluate the reaction mechanism and degradation pathways of tar compounds by using this treatment.

7 Other Activities

7.1. Dosimetry and Industrial Irradiation

(A. Miller)

7.1.1 Dosimetry for Radiation Sterilization of Medical Devices

The aim of this project is to increase the accuracy of dosimetry in industrial irradiation sterilization plants through intercomparisons and the development of standard calibration protocols. Funding for this project has been obtained from the European Commission under the Framework IV Standards, Measurement and Testing Programme. The project is being run jointly with the National Physical Laboratory, U.K.

The first intercomparison has been successfully completed, and the results analysed and distributed. Twenty seven ^{60}Co plants and eleven electron beam plants took part, representing over two thirds of the European industry. Twelve dosimetres were sent to each plant, dichromate ampoules for ^{60}Co and alanine for electron beam. The plants were asked to irradiate 8 dosimetres in the range 10-40 kGy, representing full sterilization doses, and 4 dosimetres in the range 2-10 kGy, representing the sub-process doses used in validation. The results for ^{60}Co showed plant dosimetry to be within ±10% of reference dosimetry in all cases, and 80% of the plants showed agreement within ±5%. The results for electron beams were somewhat more scattered and are shown in Figure 7.1.1. The plot shows the ratio of measured alanine dose to stated dose for each of the twelve dosimetres irradiated by each plant. Some plants show a reproducible set of results, but with a significant offset from the correct dose, whilst others show a large scatter in the individual dosimetre ratios.

A workshop, where most of the participating facilities took part, was arranged at Risø for discussion of the results from the intercomparison. A first draft of calibration guidelines will be drawn up. We hope that these guidelines will enable plants to calibrate their routine dosimetry systems with improved accuracy. The effectiveness of the guidelines will be tested with a second intercomparison.

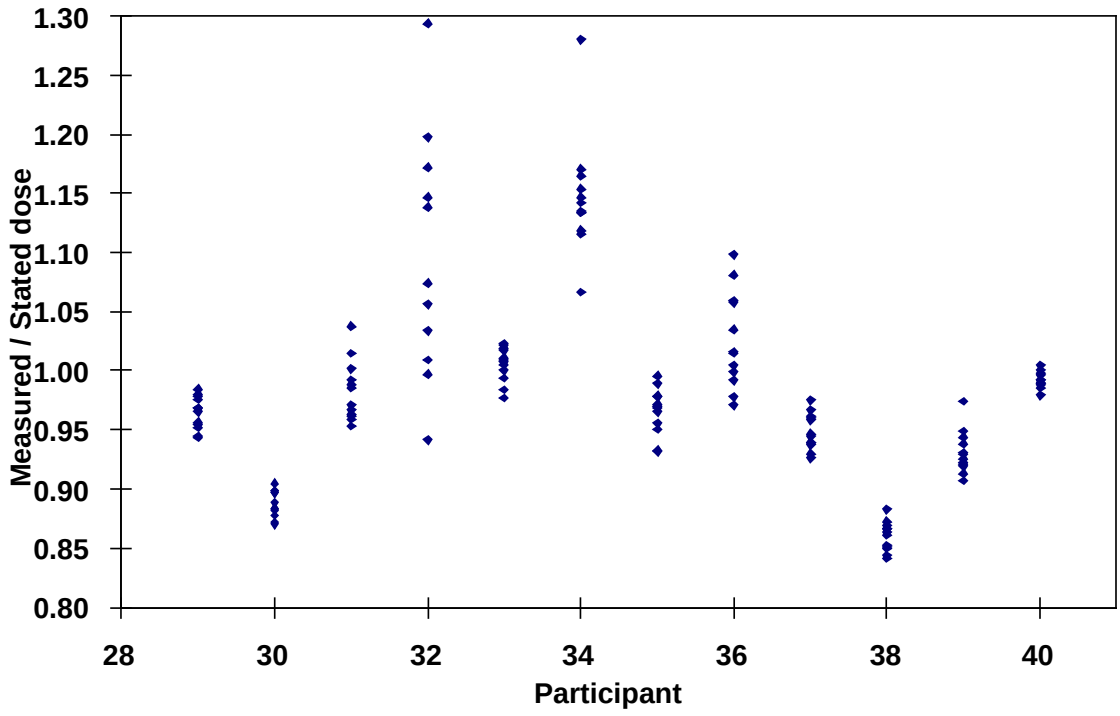

Figure 7.1.1 Ratio of measured doses divided by the doses stated by the facilities for 12 electron accelerators participating in the EU-intercomparison.

7.1.2 Accreditation for High Dose Measurements

Intercomparisons are carried out for high dose measurements and dose delivery in collaboration with NPL, U.K. and involving laboratories in Hungary, Poland and Albania. Results are not yet available.

7.1.3 Risø Industrial Irradiation

The Risø 10 MeV eletron accelerator was hired out to the Danish firm LR Plast A/S.
Irradiation on commercial basis of products *e.g.* for radiation sterilization was thereby taken over by this firm. During the year the activity was increasing and we were - also as a consequence of the back-up agreement with LR Plast and Stril AB, Sweden - irradiating an increasing amount of products.

7.1.4 Industrial Dosimetry and Consulting

The accreditation of Risø High Dose Reference Laboratory was renewed for a 5-year period by DANAK, Danish Accreditation.
The number of calibrations and measurement reports have been almost constant compared to last year, but with the implementation of the Medical Device Directive in the summer of 1998, the need for accredited dose measurements is expected to increase, as a consequence of the increased demands to documentation for radiation sterilization.
Two courses on Documentation Requirements for Radiation Sterilization were carried out in 1997 with 18 participants from 10 countries.

8 Special Facilities

8.1 The RIMI Field Station

(K. Pilegaard)

Risø's Integrated Environmental Project (RIMI) is an interdisciplinary research project aimed at the study of pathways, processes and effects of anthropogenically and biogenically derived nitrogen compounds in the terrestrial environment. Nitrogen compounds emitted to the atmosphere play an important role in changes of the atmospheric composition and oxidation capacity, deposition of nutrients and acidification of ecosystems, and there is a substantial need for more precise information on both qualitative and quantitative aspects of the problem.

The integrated project follows several of the recommendations from an international evaluation of Danish environmental research. The project combines research from different disciplines such as atmospheric transport and chemistry, plant physiology, soil biology, biochemistry and geochemistry.

The field station is central in the project. It is situated in a rural area 2 km east of Risø National Laboratory. The area is a conventional Danish agricultural area. The field station is comprised of a 10 m meteorological mast placed in the middle of a field and an instrument hut placed at the margin of the field. The mast and the hut is connected with underground wires for power supply and data transfer. Continuous meteorological measurements are carried out at the site and it serves as a reference station for air pollution monitoring in Copenhagen by the National Environmental Research Institute. In 1997 a special experiment was carried out comparing methods for the measurement of fluxes of carbon dioxide and water vapour. The experiment was a joint effort between University of Copenhagen, Departments of Geography and Botany and Risø.

The project is a joint effort with the programme "Atmospheric Transport and Exchange" in the Wind Energy and Atomspheric Physics Department, Risø.

8.2 Risø Environmental Risk Assessment Facility, RERAF

(K. Nilsson)

The first unit of the RERAF-facility was functioning by the end of 1996, and in January of 1997 the first test plants, tomatoes, were grown under Danish summer conditions in one of the 24 m^2 greenhouses with a height of 3 meters to the glass roof. The greenhouses face north and are equipped with a type of glass which allows the maximum amount of external daylight. Mobile high pressure Hg lamps are placed above the greenhouse roof giving the plant canopy maximum foton flux of approximately 1000 mmol m^{-2} s^{-1} within the range of 400-700 nm. The tomatoes grew and developed well. C3-plants, rapeseed and a C4-plant, maize followed and developed just as well.

Growth experiments were initiated, and especially the two growth chambers equipped with CO_2-controlling systems kept at 360 ppm CO_2 and 700 ppm CO_2 were used continuously for the rest of the year together with climate change studies.

Technical tests continued throughout the year and the problems were rectified as they appeared.

8.3 Dyskærgård, the Experimental Farm

(V. Haahr)

The climate during the autumn of 1996 was normal regarding rainfall, but an over average number of hours of sunshine made a good start for the winter crop. The winter and spring of 1997 were dry and sunny so less N-fertiliser was needed than expected. The summer was warm and dry so the yield was a little less than average. In the herd of Hereford cattle with 25 mother animals, 24 calves were born.

Yield mapping with a Dronningborg combine equipped with GPS and a yield metering device was again used. The demonstration field (21 ha.) with Site Specific Application of N-fertiliser showed significant differences between five sites with different treatments.

9 Publications

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9.4 Research Reports

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9.5 Other Publications

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9.6 Presentations (Oral and Posters)

Ambus, P. Emmisions of nitric oxide (NO) and nitrous oxide (N_2O) from arable land. EU-Workshop, Petten, The Netherlands 24 October.

Behrens, A. Kombinationen af ICP-MS og kemometriske metoder: Et effektivt redskab til dataanalyse. Dansk Teknologisk Institut, Det tredie Danske ICP-MS brugergruppemøde 17 April.

Behrens, A., Bibak, A., Gundersen, V., Stürup, S. The use of HR-ICPMS for routine multielemental analysis of trace elements in crops. European Winter Conference on Plasma Spectrochemistry, Gent, Belgium.

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Beier, C., Ingerslev, M., Rasmussen, L. Effects of different fertilization strategies on forest growth conditions and vitality. "Experimental Ecosystem Manipulation Workshop", Jasper, Canada 14-17 October.

Engvild, K. Natural chlorinated compounds and their function in plants and other eucaryotic organisms. TU Dresden, Germany 21 October.

Engvild, K.C. "Top-dying" and "Red decline" of Norway spruce may be identical and not explained by the ammonium hypothesis. XVIII Congress of SPPS, Uppsala, Sweden 12-17 June.

Feilberg A. Field measurements of airborne particulate polycyclic aromatic compounds. ERCA'97, Grenoble 14-17 January.

Feilberg, A. Modified analysis method for particulate PAH, S-PAC and oxygenated PAH by capillary GC-Ion trap MS. ERCA'97, Grenoble 14-17 January. Poster.

Gissel-Nielsen, G. Summary. Nutrient dynamics. 11. World Fertilizer Congress, Gent, Belgium 7-13 September.

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Gissel-Nielsen, G. Trace elements essential or beneficial in the human and animal food chain. Kompendium til kursus i planternes ernæring, RVAU, 13 January.

Grøn, C. Hvad er kvalitet i prøvetagning? ATV Grundvands-komitteens møde: Kvalitet i miljørpøvetagning Jord, poreluft og grundvand (in Danish).

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Grøn, C. Dannes chlorerede organiske stoffer naturligt i jord og grundvand? (in Danish). The Royal Veterinary and Agricultural University, Copenhagen, Denmark 20 March.

Grøn, C. Hovedkonklusionerne fra ATV-mødet den 28. oktober 1996 "Hvordan kan vi bruge forskningen på jord- og grundvandsområder?". ATV Grundvandskommiteens Vintermøde om grundvandsforurening 11-12 March (in Danish).

Grøn, C. Processer i skovbunden og naturstoffer i grundvandet (in Danish). The Royal Veterinary and Agricultural University, Copenhagen, Denmark 2 December.

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Hatzack, F.A, Johansen, K.S., Rasmussen, S.K. Low phytin grain mutants in barley. In: Workshop on the Biochemistry of Plant Phytase and Phytases. Schæffergården, Copenhagen 25-28 October.

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Helweg, C. Environmentally important physical-chemical properties of polar polycyclic organic material, especially azaarenes. University of Roskilde 18 April.

Holcman, J. Equilibria in oxydation of benzoic acid. RINOXA meeting, Strasbourg, France 5-6 March.

Holcman, J. Kinetic parameters and activation energies for reactions of some atmospheric model compounds with OH and NO_3 radicals. RINOXA meeting, Zürich, Switzerland 25 Sepember.

Holst, P.H. Isolation and identification of natural chlorocompounds in crop plants. VTT, Espoo, Finland 30 January.

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Symbion, Copenhagen 12 December.

Jacobsen, F., Holcman, J., Sehested, K. Reactions of Mn^{2+}_{aq} with Ozone and $Mn(III)_{aq}$ with H_2O_2 Stopped-flow and Pulse Radiolysis Study. PULS'97. 5th International Meeting in Pulse Investigation in Chemistry, Biology and Physics, Szczyrk, Poland 13-19 September. Poster.

Jensen, E.S. Intercropping: a practise to improve the utilization of N-sources. 11th World Fertilizer Congress, Gent, Belgium 7-13 September.

Jensen, E.S. Measuring the release of N from organic materials using indirect or direct ^{15}N methods. IAEA, Seibersdorf laboratories. Meeting of IAEA Consultants 16-17 June.

Jensen, E.S. Nitrogen cycling in cropping systems with pea. UNIP meeting: La matrise de l'azote dans les rotations incluant du pois, Paris 19 June.

Jensen, E.S. Rhizodeposition of N during the growth of pea. UNIP meeting: La matrise de l'azote dans les rotations incluant du pois, Paris 19 June.

Johannessen, M., Jørgensen, R.B., Mikkelsen, T.N. Genetic variation and CO_2 exploitation in varieties of oilseed rape (*Brassica napus* L.) ISH-symposia, Brassica-97, Renne, France.

Jørgensen, J.H., Østergård, H. Resistens mod bladsygdomme i byg. 14. Danske Planteværns-konference 1997. Sygdomme og skadedyr.

Jørgensen, R.B. Betænkeligheder ved dyrkning af gensplejsede planter. Indlæg på Statens Husholdningsråds debatdag om genteknologi i Eigtveds Pakhus 13 March.

Kläning, U., Sehested, K. Hydrogen Atom Transfer by the Hydrolysis Reaction $O^- + H_2O \rightarrow OH^- + OH$ studied by Oxygen Isotope Exchange. Forschungszentrum Rossendorf, Dresden, Germany 12 September.

Kunzendorf, H. Tracing and Using the Chernobyl Signal in Baltic Sea Sediments. Physics Laboratory Ionizing Radiation Division Seminar. United States Department of Commerce National Institute of Standards and Technology Gaithersburg, Maryland, USA 24 March.

Kunzendorf, H. Variability of recent sedimentation rates in the North Central Basin of the Baltic Sea (BASYS-7). The fifth marine geological conference. Lithuanian Insitute of Geology 6-11 October. Vilnius, Lithuania.

Kunzendorf, H., Kuijpers, A Recent sedimentation history in the Norwegian Channel compared to Faroe Shelf sedimentation. European North Atlantic Margin. 1st ENAM II Workshop. Salzau, Germany 11-13 April.

Laturnus, F., Grøn, C., Adams, F.C. Is spruce forest soil a source for volatile chlorocarbons. 1st Euroconference on Environmental Analytical Chemistry, Neusiedl am See, Austria 11-17 October.

Miller, A. Dosimetry requirements derived from the Sterilization standards. 10th International Meeting on Radiation Processing, Anaheim, CA, USA 12-16 May.

Miller, A. GMP and ISO 9002: Issues relevant accreditation. IAEA/KFDA Training Course on Dosimetry and Quality Assurance in Radiation Processing. Korea Food & Drug Administration (KFDA), Republic of Korea 24-27 November. Seven speeches.

Miller, A., Mehta, K. General introduction to radiation processing. IAEA/ KFDA Training Course on Dosimetry and Quality Assurance in Radiation Processing. Korea Food & Drug Administration (KFDA), Republic of Korea 24-27 November.

Miller, A., Sharpe, P. Quality Control Procedures for Industrial Radiation Sterilization. Conference on Industrial Technologies, Toulouse, France 27-30 October.

Nath, B.N., Kunzendorf, H., Plueger, W.L. Sedimentary processes controlling the geochemistry of recently deposited clayey sediments from Vembanad Lake and the adjoining continental shelf, a tropical coastal environment on the southwest coast of India. Muddy sedimentology, geochemistry, and ecology of muddy coasts. Wilhelmshaven, Germany 1-5 September.

Nielsen, T. FENPAC: Fate, plant uptake and effects of N-PAC, an important group of components in creosote and tar. Workshop in Danish Centre of Ecotoxicological Research, National Environmental Institute, Roskilde, Denmark 21 August.

Nielsen, T. Interactions between tropospheric ozone chemistry in the northerly Atlantic Regions and over the European Continent. EUROTRAC-TOR2 Workshop, Swedish Environmental Research Institute, Gothenburg, Sweden 4-5 September.

Nielsen, T., Gissel-Nielsen, G., Helweg, C., Feilberg, A., Hansen, P.E. N-PACL Phytotoxicity and soil sorption. 16th International symposium on polycyclic aromatic hydrocarbons. Charlotte, NC, USA 4-8 November.

Rasmussen, L., Beier, C., Breemen, N. van, Visser, P. de, Matzner, E., Kreutzer, K., Schierl, R., Farrell, E.P. EXMAN - Exprimental MANipulations of forest ecosystems in Europe. "Experimental Ecosystem Manipulation Workshop", Jasper, Canada 14-17 October.

Rasmussen, L. Results from the EXMAN Project - EXperimental MANipulation of Forest Ecosystems in Europe. "Experimental Ecosystem Mannipulation Workshop", Jasper, Canada 14-17 October.

Samsøe-Petersen, L., Plöger, A., Vejrup, K., Jensen, E.S., Bennetzen, A., Grøn, C. Determination of plant uptake from sewage sludge for selected organic contaminants. Specialty Conference on Management and Fate of Toxic Organics in Sludge Applied to Land. Copenhagen 30 April-2 May.

Schmidt, A.S. Research in

lignocellulose utilization at Risø National Laboratory. National Center for Food Technology (CTAA), the Brazilian Agricultural Research Corporation (EMBRAPA) Rio de Janeiro, Brazil 12 September.

Sehested, K. Oxydation of Phenols by OH and NO_3 radicals. RINOXA meeting, Strasbourg, France 5-6 March.

Stürup, S. Determination of calcium and zink isotopic ratios using ICP-HRMS. 6th Nordic Symposium on Trace Elements in Human Health. University of Roskilde, Denmark 26 June-2 July.

Stürup, S. Determination of deuterium, bromine and calcium is clinical samples using HR-ICPMS. 1997 European Winther Conference on Plasma Spectrometry. Gent, Belgium. Book of abstracts, University of Gent January 12-17.

Stürup, S. Determination of isotopic ratios of zinc and calcium in human samples using ICP-HRMS. Trace Elements in Human Health and Disease, Book of Abstracts. University of Roskilde, Denmark 29 June-3 July.

Stürup, S. ICPMS til bestemmelse af uorganiske forbindelser. Levnedsmiddelselskabet, Ingeniørhuset 25 September.

Stürup, S. Measurement of isotope ratios on the Plasma Trace 2 ICPMS. European Inorganic users meeting & ICP-MS Seminar, Forschumgszentrum Karlsruhe, Germany 16-17 April.

Zagórski, Z., Sehested, K. Transient and stable radicals from deamination of alanine. PULS'97, 5th International Meeting in Pulse Investigation in Chemistry, Biology and Physics, Szczyrk, Poland 13-19 September. (Oral and poster).

10 Education

10.1 Doctorates

Jensen, E.S. (Dr.agro. Thesis), (1997) The role of grain legume N_2 fixa-tion in the nitrogen cycling of temperate cropping systems. Risø National Laboratory and The Royal Veterinary and Agricultural University, Copenhagen, Denmark - Risø-R-885 (EN), 107 p.

10.2 Titles of Honour

Gissel-Nielsen, G. Honouree Professorship at The Royal Veterinary and Agricultural University, Copenhagen, April 1997.

Nielsen, O.J. Honouree Professorship at University of Roskilde, December 1997.

10.3 Ph.D. Theses

Behrens, A. (1997) Determination of Trace Elements by Inductively Coupled Plasma Mass Spectrometry Combined with Multivariate Data Aanalysis. Ph.D. Thesis, Risø National Laboratory and Technical University of Denmark. Risø-R-973(EN), 143 p.

Bilde, M. (1997) Atmospheric Chemistry of Halogenated Methanes. Ph.D. Thesis. Risø National Laboratory and University of Copenhagen, Denmark.

Helweg, C. (1997) Methods for Determination of Environmentally Important Physical-Chemical Properties of Polar Polycyclic Organic Material. Ph.D. Thesis, Risø National Laboratory and University of Roskilde, Denmark.

Jacobsen, F. (1997) Ozonization of Transition Metal Ions. Ph.D. Thesis. Risø National Laboratory and University of Roskilde, Denmark, 81 p.

Jørgensen, F. (1997) Symbiotic N_2 fixation in mixtures of perennial ryegrass and white clover under low-input conditions. Ph.D. Thesis. Risø National Laboratory and The Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Landbo, L. (1997) Introgression from Oilseed Rape *(Brassica napus)* to Weedy *Brassica campestris* - an Avenue for the Escape of Transgenes? Ph.D. Thesis, Risø National Laboratory and University of Aarhus, Denmark. 137 p.

Møgelberg, T.E. (1997) Atmospheric Chemistry of Halogenated Compounds. Ph.D. Thesis. Risø National Laboratory and University of Copenhagen, Denmark. 216 p.

10.4 M.Sc. Theses

Bach, L.F. (1997) A new PCR-based Method for Isolating Microsatellites in Barley. Risø National Laboratory and The Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Ghasemi, F. (1997) Oprensning og karakterisering af humusstoffer fra Skidendam højmose og deres kompleksdannelse med terbium og europium. Risø National Laboratory and University of Copenhagen, Denmark.

Hansen, H.S. (1997) Oprensning, karakteristik, fluorescens og kemometri på humusstoffer. Risø National Laboratory and University of Copenhagen, Denmark.

Hansen, S.R. (1997) Fosfors effekt på interaktioner mellem arbuskulære mykorrhiza svampesamfund og hør. Risø National Laboratory and University of Roskilde. 61 p.

Jensen, M.T. (1997) Mapping and Identification of the Mating Type (MAT) Locus in the Barley Powdery Mildew Fungus *Erysiphe graminis* f.sp. *hordei*. Risø National Laboratory and University of Odense, Denmark. 73 p.

Scharff, A.M. (1997) Arbuskulær mykorrhiza svampes indflydelse på fytoalixin indholdet i soyabønne rødder. Risø National Laboratory and University of Roskilde. 52 p.

10.5 External Examiners

Engvild, K.C. Censor in plant physiology at the University of Aarhus.

Giese, H. Censor in molecular biology and plant biochemistry at The Royal Veterinary and Agricultural University, Copenhagen. Censor in molecular biology and plant physiology at University of Aarhus.

Grøn, C. Member of the panel of external examines at the Danish Engineering Educations.

Gundersen, V. Censor in chemical analysis at Technical University of Denmark.
Censor in mechanical engineering at Aalborg University.

Jensen, A. Censor in biology at all Danish universities.

Jensen, E.S. Censor in plant nutrition and crop physiology at The Royal Veterinary and Agricultural University, Copenhagen.

Jørgensen, J.H. Censor in plant breeding and plant pathology at The Royal Veterinary and Agricultural University, Copenhagen.

Jørgensen, R.B. Censor in molecular biology and plant physiology at University of Aarhus.

Nielsen, O.J. Censor in chemistry at University of Copenhagen and University of Odense.

Pilegaard, K. Censor in ecology, University of Copenhagen.
Censor in air pollution, Technical University of Denmark.

Rasmussen, S.K. Censor in molecular biology and plant biochemistry at The Royal Veterinary and Agricultural University, Copenhagen and University of Aarhus.

Rosendahl, L. Censor in molecular biology and plant physiology at University of Aarhus.

Wilbrandt, R. Censor at University of Odense.

Østergård, H. Censor in biology at University of Aarhus and University of Copenhagen.

10.6 External Teaching and Lectures

Christiansen, S.K. Lectures in Molecular Plant Pathology at The Royal Veterinary and Agricultural University, Copenhagen, February.

Gissel-Nielsen, G. Mikronærings-stoffer essentielle for animalsk ernæring. - 2 lectures at The Royal Veterinary and Agricultural University, Copenhagen 20 November (in Danish).

Jakobsen, I. Lectures in Plant Biochemistry at The Royal Veterinary and Agricultural University, Copenhagen 4 November.

Jakobsen, I. Mykorrhizas betydning for planters ionoptagelse. - Tune Landboskole, Denmark 13 August (in Danish).

Jensen, E.S. Planters afsætning af N og C i rhizosfæren. Lecture at The Royal Veterinary and Agricultural University, Copenhagen 21 October (in Danish).

Rosendahl, L. Lectures in Plant Biochemistry at The Royal Veterinary and Agricultural University, Copenhagen 14 October.

Stürup, S. Course of Chemistry 3AØ at the University of Copenhagen.

Thingstrup, I. Field populations of mycorrhizal fungi: test of their phosphorus transport to host plants. University of Roskilde, Denmark 21 February.

Thingstrup, I. Lectures in Plant Biology at The Royal Veterinary and Agricultural University, Copenhagen 22 April.

11 Exchange of Scientists

Backes, G. Leave of absence as Post doc at Technische Universität München, Freising-Weihenstephan, Germany (2 months).

Bobrowski, K. Institute of Nuclear Chemistry and Technology, Warsaw, Poland (5 weeks).

Bunjoedchowsahu, R. Department of Plant Pathology, Kasetsart University, Thailand (3 months).

Butterworth, L. Final part of Ph.D. project at Department of Brassicas and Oilseed Research, John Innes Centre, Norwich, U.K. (6 months).

Curtis, P. Biological Station, University of Michigan, USA (6 months).

Fujii, T. Japan Environmental Agency, Tsukuba, Japan (2 weeks).

Garroud, H. University of Pan, France (1 week).

Germon, F. Ecole Superieure Dágriculture, France (3 months).

Giese, H. Leave of absence as Visiting Professor at Okayama University, Japan (4 months).

*Gluszewski, W.*J. Institute of Nuclear Chemistry and Technology, Warsaw, Poland (1 week).

Hallgren, L. Department of Plant Physiology, Goeteborg University, Sweden (3 months).

Jahoor, A. Leave of absence at Technische Universität München, Freising-Weihenstephan, Germany (2 months).

Ketola, R.A. VTT Chemical Technology, Finland (1 month).

Kristensen, B.K. Leave of absence as visiting researcher at Cereal Disease Laboratory, US Department of Agriculture, St. Paul, Minnesota, USA (4 months).

Lyngkjær, M. Leave of absence as Post doc at Institute of Grassland and Environmental Research (IGER), Aberystwyth, U.K. (12 months).

Mouritzen, P. Leave of absence as Post doc at Australian National University, Canberra, Australia (3 months).

Mouritzen, P. Technical University of Denmark (5 months).

Munoz, A. Instituto Technológico de Costa Rica (3 months).

Nicolaisen, M. Technical University of Denmark (3 months).

Paucot, H. University of Pan, France (1 week).

Panta, P.P. Institute of Nuclear Chemistry & Technology, Warsaw, Poland (2 weeks).

Ratajczak, E. Department of Physical Chemistry, Medical Academy, Wroclaw, Poland (4 months).

Roberts, T.H. Technical University of Denmark (6 months).

Schaerer, H.J. ETH, Zürich, Switzerland (4 weeks).

Snow, A. Department of Plant Biology, Ohio State University, USA (6 months).

Strzelczak-Burlinska, G. Institute of Nuclear Chemistry and Technology, Warsaw, Poland (3 weeks).

Tomiuk, J. Klinische Genetik Universität Tübingen, Germany (6 months).

Tupouniua, S. Research Division, MAF, Nuku'alofa, Tonga (1 month).

Yee, W.A. Santa Clava University, California, USA (5 months).

Zona, R. University of Vienna, Austria (1 month).

Wallington, T. Ford Motor Co., Dearborn, USA (2 weeks).

Wu, Boqian, National Center for Gene Research, Chinese Academy of Sciences, Shanghai, P.R. China (4 months).

12 Guest Lectures

Olsson, S. The Royal Veterinary and Agricultural University, Copenhagen, Denmark: "Næringsoptagelse i *Rhizoctonia"* (in Danish), 6 March.

Hauser, T. University of Copenhagen, Denmark: "Hybridisering mellem raps og ukrudtsagerkål: fitness og genotype forskelle i F1, F2 og BC1" (in Danish), 10 April.

Olesen, A. The Royal Veterinary and Agricultural University, Copenhagen, Denmark: "Protoplastkultur og transformation af rajgræs - effekt af genotype og kultursystem" (in Danish), 17 April.

Hatzak, F. University of Ulm, Germany: "Purification and characterisation of promoter binding proteins from pea mitochondria", 23 April.

Michelsen, A. University of Copenhagen, Denmark: "Mykorrhizasvampens betydning for subarktiske planters optagelse af kvælstof, belyst ved deres naturlige indhold af ^{15}N" (in Danish), 1 May.

Weidema, I. University of Copenhagen, Denmark: "Betydning af landskabshistorien i forhold til nuværende genetisk diversitet i plantepopulationer" (in Danish), 15 May.

Guldman, L. University of Aarhus, Denmark: "Isolering og karakterisering af glycoproteiner med en formodet lokalisering i det peribakteroide space i ærterodknolde" (in Danish), 22 May.

Pedersen, K. Systems Analysis Department, Risø National Laboratory, Denmark: "Probabilistic risk assessment illustrated by a biological case", 11 September.

Snow, A. Department of Plant Biology, Ohio State University, USA: "Ecological studies of crop-weed hybridisation: case studies of sunflower, radish, and squash, 18 September.

Roberts, T.H. University of Lund (present: Technical University of Denmark): "The plant mitochondrial electron transport chain: Identification and properties of the multiple NAD(P)H dehydrogenases", 25 September.

Schierup, M. University of Aarhus, Denmark: "The effect of enzyme heterozygosity on growth in the self-incompatible species *Arabis petraea*", 23 October.

Curtis, P.S. Biological Station, University of Michigan, USA: "Forest responses to rising atmospheric CO_2: results from primary and meta-analytic studies", 30 October.

Didion, T. Department of Yeast Genetics, Carlsberg Laboratory, Denmark: "Uptake of branched amino acid in *Saccharomyces cerevisiae*", 6 November.

Jaroszewski, J. The Royal Danish School of Pharmacy, Copenhagen, Denmark: "NMR spektroskopi på cellekulturer" (in Danish), 13 November.

Oliver, R. Carlsberg Laboratory, Denmark: "What does it take to be a biotrophic fungal plant pathogen", 20 November.

Hellgren, L. Göteborg University, Sweden: "The impact of ozone on lipid composition, lipid metabolism, and the dynamical, properties of plasma membranes", 11 December.

13 Committee Membership

13.1 National

Giese, H. OECD Committee for Biotechnology.
Board of Danish Polar Center.
Danish Society for the Conservation of Nature, Committee for Environmental Issues.

GisselNielsen, G. Danish Academy of Technical Sciences.
Governing board of Danish Institute of Plant and Soil Science.
Danish Society for the Conservation of Nature, Committee for Environmental Issues.

Grøn, C. Board of the Soil and Ground Water Contamination.
Commitee of the Danish Council of Technical Sciences. Danish Standardization Association.

Committee on Environmental Analyses.

Head of Centre for Sustainable Land Use and Management of Contaminants, Carbon and Nitrogen, an open centre under the Danish Environmental Research Programme, 1997-2000

Jensen, A. Member of the board of directors for Pajbjerg Foundation, Denmark.
DCAR, Danish Center of Atmospheric Research.
DaFoLa, Danish Center for Forest and Landscape Ecosystem Research.
Invited member of The Rockwool Foundation Research Unit discussion group “how to value “nature” in environmental policy”.
Chairman of the evaluation panel conserning aquatic and terrestrial ecotoxicology in The Danish Environmental Research Programme.
Chairman of the steering committee for the international evaluation of the Danish university educations in biology.
Member of The Danish Academy of Technical Sciences.

Jensen, E.S. Member of The Danish Agricultural and Veterinary Research Council.
Member of the scientific board for the Danish Pesticide Research Programme.
Governing Board of Danish Institute of Agricultural Science.

Jørgensen, J.H. Danish Gene Bank Committee.
Coordination group for resistance and virulence in cereals and cereal pathogens in Denmark.

Jørgensen, R.B. Member of the Danish Environmental Appeal Board.
Board of Centre for Effects and Risks of Biotechnology in Agriculture (The Danish Environmental Research Programme.

Larsen, E. Danish Society of Mass Spectrometry.
The Danish National Committee for Chemistry.

Miller, A. Danish Medical Device Association (DMDA).
Sterilization committee.
Danish Standards Association.
Committee S 259 on Sterilization of Medical Equipment. (Chairman).

Nielsen, O.J. The National Committee for The International Geosphere-Biosphere Programme (IGBP).

Pilegaard, K. Danish Centre for Atmospheric Research (DCAR) Working Group on effects. (Chairman).
Committee on the national strategy for public agricultural research. Subgroup on forest and landscape.

Rasmussen, S.K. Society of Danish Engineers, Board of Chemistry Section.
Board of Danish Cereal Society.

Rosendahl, L. Member of Committee of Censors in biology at all Danish universities.

Schmidt, A.S. Working committee in Biotechnology, Chemical Engineering Group, The Engineering Society of Denmark (IDA).

Østergård, H. Ph.D. Committee for Education, The Royal Veterinary and Agricultural University, Copenhagen.
Coordination group for resistance and virulence in cereals and cereal pathogens in Denmark.
Board of Centre for Effects and Risks of Biotechnology in Agriculture (The Danish Environmental Research Programme.

13.2 International

Ambus, P. U.S. Trace Gas Network (TRAGNET), working group.

Giese, H. Editorial board, Hereditas and Plant Pathology on line.
OECD committee for Biotechnology.

Grøn, C. Board member of the Nordic branch of the International Humic Substances Society.

Jakobsen, I. Management committee for COST Action 8.21: Arbuscular mycorrhizas in sustainable soilplant systems.

Jensen, A. Member of an EEC expert panel for the collaboration on higher educations between European countries and USA.

Jensen, E.S. Editorial Board of ‘Plant and Soil’.
Sectionboard for Soils and Fertilizers, Scandinavian Association of Agricultural Scientists.
National delegate in OECD cooperative research programme: Biological Resource Management for Sustainable Agricultural Systems.

Jensen, J. International coordinator, barley chromosome 5; International Barley Nomenclature Committee.

Jørgensen, J.H. Co-editor of ‘Euphytica’.
International coordinator for disease and pest resistance genes in barley.
Working group cereal, Nordic Gene Bank (Chairman).

Jørgensen, R.B. Member of Panel of Experts, International Biosafety Forum, Third World Network.

Kunzendorf, H. Editorial Board of 'Marine Georesources and Geotechnology'.

Larsen, E. European Commission, Access to Large-Scale Facilities, Technical Audit of the HCM-LSF contracts.

Miller, A. CEN TC 204 WG2 Sterilization by ionizing radiation. Member.
ISO TC 198 Sterilization of Health Care products. Member.
Int. Symposium on Nuclear and Related Techniques in Agriculture, Industry, Health and the Environment. Member of Scientific Advisory Committee.
13th Radiochemical Conference, Czech Republic. Member of Int. Advisory Board.
Editor-in-Chief Radiation Physics and Chemistry.
10th International Meeting on Radiation Processing. Member of programme committee.
International Electrotechnical Commission (IEC), Subcommittee 15B, Working Group 2 on Endurance Tests. Radiation. Corresponding member.
Organisation Internationale de Metrologie Legale (OIML). TC-15. Measuring measurements for ionizing radiation. Member.

Nielsen, O.J. EUROTRAC International Executive Committee.
COST-611 Working Party 2 Steering Committee, Atmospheric and Photochemical Processes.
Steering Committee for NORSAC (Nordic Symposia on Atmospheric Chemistry).

Nielsen, T. The board of Nordic Society of Organic Pollutants.

Pilegaard, K. Member of steering committee for BIATEX-2 under EUROTRAC-2.

Rasmussen, L. Member of the Swedish Research Council for Forestry and Agriculture, Section for Biogeochemistry.
Member of Editorial Board for Forest Ecology and Management.

Thomsen, A.B. IEA - Bioenergy agreement Task XIII. Bioconversion activity. Alternative member of committee.

Østergård, H. COST, chairman of Management Committee "Population studies of airborne pathogens on cereals as a means to improve strategies for disease control".
Editorial board of Agronomie.

14 Seminars and Courses Organized

COST Meeting on Epidemiological Parameters and Modelling, Risø National Laboratory 27-28 February (*H. Østergård*).

NJF Workshop "Phosphorus balance and utilization in agriculture – towards ??? ability", Stockholm, Sweden 17-19 March (*I. Jakobsen*).

Training course on Validation and Process Control for Electron Beam Sterilization, Risø National Laboratory 16-20 June and 25-29 August (*A. Miller*).

Meeting on the Quality of Environmental Sampling – Soil, Soil Air and Ground Water, arranged by the Soil and Ground Water Contamination Committee of the Danish Council of Technical Sciences 5 November (*C. Grøn*).

Nordic Energy Research Programme – Bioenergy Processes. Ethanol Research Seminar at Risø National Laboratory 25-26 November (*A.S. Schmidt*).

Plant Cell Walls – Raw Material of the Future, at the Engineering Society of Denmark, Copenhagen 26 November (*A.S. Schmidt*).

Ph.D. course "Seminars in Plant Microbe Symbiosis", January-December (*L. Rosendahl, I. Jakobsen, H. Giese*).

15 Scientific Results and Finances

15.1 Scientific Results

Plant Biology and Biogeochemistry Department	
	Results 1997
Basic research and development (man-month)	361
Research programmes (man-month)	781
Commercial contracts (man-month)	77
Technical support for research (man-month)	66
Management (man-month)	118
Total	1403
Dissemination of results	
Papers in international journals and books	84
Papers in Danish journals and books	17
Risø reports, R , M og I	6
Danish books and reports	11
International books and reports	4
Other publications	6
Papers in conference proceedings	30
Other internationale conference contributions	90
Other Danish conference contributions	30
Patent proposals	0
Apprentices and trainees	11
Conferences (arranged)	7
Networking and collaboration	
Ph.D. students (number)	21
Ph.D. degrees (number)	5
Risø leave of abcence (man-month)	21
Visiting scientists at Risø (man-month)	29
Scientific papers reviewed (number)	162
Committees for Ph.D.thesis, promotion of scientists, senior scientists, professors (number)	17
Committee memberships (number)	36
Contracts with companies (number)	66
Collaboration with companies (man-month)	172
Collaboration with research institutes (number)	0
Collaboration with research institutes (man-month)	462
Contracts with public authorities (number)	2
Collaboration with public authorities (man-month)	7

15.2 Finances

The activities of the Department are supported by a combination of government appropriations, project funds from national and international research programmes and fully commercial industrial contracts.

1997	DKK 1000	USD 1000
Income		
Dept.'s share of Risø's government appropriations	39,000	5,744
Programmes and contracts	29,891	4,402
Total	68,891	10,146
Expenditure		
Salaries	53,041	7,812
Operating expenses	13,140	1,935
Durable equipment	2,710	399
Total	68,891	10,146

Additional funding has been obtained for Ph.D. grants, Post. doc. fellowships, apprentices and trainees.

16 Personnel

The research activities are organized into 5 research programmes and supported by 3 special facility units.

The Department includes 69 full time scientific staff members and 45 full time technical staff members. The list also includes short-term employees.

Head of Department:
Arne Jensen

Research Programmes
Atmospheric Chemistry and Air Pollution
Head: Ole John Nielsen.
Resistance Biology and Plant Genetics
Head: Hanne Østergård.
Plant Ecosystems and Nutrient Cycling
Head: Gunnar Gissel Nielsen.
Trace Elements and Organic Matter
Head: Vagn Gundersen.
Plant-Microbe Symbiosis
Head: Henriette Giese (constituted).

Special Facilities
Growth chambers, Risø Environmental Risk Assessment Facility (RERAF), green-houses and the experimental farm, Dyskærgaard.
Head: Vagner Haahr.
Risø High Dose Reference Laboratory.
Head: Arne Miller.
Risø Integrated Environmental Facility (RIMI).
Head: Kim Pilegaard.

16.1 Scientific Staff

Ambus, Per
Backes, Gunter
Behrens, Annette (until 31.08)
Beier, Claus
Bibak, Allan
Bjergbakke, Erling
Bogø, Annette (until 31.01)
Christiansen, Solveig Krogh
Clemmensen, Alireza (until 31.08)
Egsgaard, Helge
Engvild, Kjeld C.
Fenger, Jørgen
Gavito, Mayra
Giese, Henriette
Gissel Nielsen, Gunnar
Grøn, Christian
Gundersen, Pernille
Gundersen, Vagn
Habibzadeh, A.
Hatzack, Frank
Herly, Lene
Holcman, Jerzy
Haahr, Vagner
Jahoor, Ahmed
Jakobsen, Iver
Jensen, Erik Steen
Jensen, Jens
Jørgensen, Bjarne
Jørgensen, Finn
Jørgensen, Jørgen Helms (until 31.08)
Jørgensen, Rasmus Nyholm
Jørgensen, Rikke Bagger
Keszthelyi, Tamas
Kilen, Hans Henrik
Kunzendorf, Helmar
Larsen, Elfinn
Laturnus, Frank
Lynggård, Bent
Lyngkjær, Michael
Mikkelsen, Teis Nørgaard
Miller, Arne
Mouritzen, Peter (until 31.07)
Nielsen, Ole John
Nielsen, Torben
Nilsson, Karen
Offersgaard, Jesper
O'Hara, Robert
Pagsberg, Palle
Pedersen, Carsten
Pilegaard, Kim
Plöger, Annette (until 31.03)
Rasmussen, Lennart
Rasmussen, Søren Kjærsgård
Rosendahl, Lis
Schmidt, Anette Skammelsen
Schweiger, Peter
Sehested, Jens
Sehested, Knud
Sillesen, Alfred Heegaard
Stürup, Stefan
Thingstrup, Ida
Thomsen, Anne Belinda
Vejrup, Karl V. (until 30.09)
Wilbrandt, Robert
Woidemann, Anders
Østergård, Hanne

16.2 Technical Staff

Andersen, Bente
Andersen, Margit Elm
Brandt, Lis
BrinkJensen, Merete
Corfitzen, Hanne
Djurdjevic, Stanko
Fernqvist, Tomas
Fosskov Jensen, Jette
Gade, Poul
Gudiksen, Peter
Hansen, Ina
Hasselbalch, Finn
Henriksen, Ebbe (until 31.10)
Ibsen, Elly
Jakobsen, Mia (until 31.12)
Jensen, Birgit
Jensen, Ellen Møller
Johansen, Torben (until 31.10)
Karlsen, Aage
Koutras, Charlotte
Kristiansen, Bo (until 31.10)
Kvamm, Birte
Larsen, Erik Engholm
Larsen, Fritz
Larsen, Ingelis
Larsen, Inge Merete
Lilholt, Ulla
Madsen, Michael B. (until 31.10)
Meltofte, Liselotte
Møller, Anette
Nielsen, Jette Bruun
Nielsen, Lars Møller (until 31.10)
Nielsen, Torben Brokjær (until 09.09)
Nielsen, Vagn Aage
Olsen, Anette
Olsen, Anne
Olsen, Inge
Sillesen, Anerikke
Sørensen, Poul
Tung, Tran Duc Tuan
Thygesen, Maria
Vestesen, Hans
Vinther Kristensen, Lis
Wojtaszewski, Hanne

16.3 Office Staff

Bay, Kirsten
Borring Sørensen, Marit
Bækmark, Anni
Frandsen, Anette
Jakobsen, Inger
Jensen, Hanne
Kristensen, Ingrid (until 30.04)
Krogh, Helle
Petersen, Lis

16.4 Ph.D. Students

Bilde, Merete
Borgen, Anders
Butterworth, Lisa A.
Christensen, Lene Krogh
Eriksen, Lars B.
Fauser, Patrik
Feilberg, Anders
Grage, Mette Marie
Grell, Morten
Guldmann, Lise-Lotte
Helweg, Christian
Holst, Pia Bachmann
Jacobsen, Frank
Johansen, Katja Salomon
Johansen, Runa Ulsøe
Jørgensen, Finn
Klinke, Helene B.
Kristensen, Brian K.
Møgelberg, Trine
Møller, Marianne Gellert
Platz, Jesper
Ravnskov, Sabine
Reynisson, Johannes
Scharff, Anne Marie
Simonsen, Anna Carina Wiborg
Stürup, Stefan

16.5 M.Sc. and B.Sc. Students

Eriksen, Rasmus
Eydesgaard, Eyd Jona
Hansen, Steen Roed
Jensen, Anne Louise Borup
Johannessen, Marina
Larsen, Vibeke Helene
Madsen, Christian Hald
Monrad, Annette
Sørensen, Jacob Skov
Wittenhorst, Vincent
Rudbeck, Annette
Stein, Thomas N.N.
Møller, Carsten W.
Haselmann, Kim
Poulsen Morten
Pedersen, Lars Meinild

16.6 Apprentices

Bultoft, Hanne
Engelhartd, Stina
Goldberg, Kristina Maria
Harder, Brit Johanna
Jespersen, Tina Grith
Kendix, Elsebeth
Nielsen, Christian Leon
Olsen, Carina Nykjær
Pedersen, Kenneth Munk
Schmidt, Ewa Wanda
Thorsgaard, Birgitte

17 Acronyms

AFLP	Amplified Fragment Length Polymorphism
BASYS	Baltic Sea System Study
BDE	Bond Dissociation Energy
CEVENT	Centre for in situ re-mediation of soil and groundwater by Ventilation
CFC	Compound: Chlorine, Fluorine, Carbon
CLIMEX	Climate Change Experiment
DANAK	Danish Accreditation Scheme
DH	Chromosome-Doubled Haploid
DIPSS	Danish Institute of Plant and Soil Science
DMU	Danish National Environmental Research Institute
DOAS	Differential Optical Absorption Spectroscopy
DTU	Danish Technical University
Egh	*Erysiphe graminis* f.sp. *hordei*
ENAM	European North Atlantic Margin
EST	Expressed Sequence Tag
EUROFLUX	Effects of CO_2 exchange over European forests
EUROTRAC	European Experiment on Transport and Transformation of Environmental Relevant Trace Constituents of Anthropogenic and Natural Origin
EUROVOC	Control Strategies for European Air Quality Based on the Tropospheric Oxidation Characteristics of Volatile Organic Compounds
FOREXNOX	Effects of nitrogen oxides on European forests
FORMONA	Formation and Occurrence of Nitrous Acid in the Atmosphere
FØTEK	Danish Food Technology and Development Programme
GDC	Gamma Dating Centre
GEUS	Danmarks og Grønlands Geologiske Undersøgelser
GFP	Green Fluorescent Protein
GLOCONA	Global Changes of tropospheric Ozone chemistry in the North Atlantic regions
GPS	Global Positioning System
GUS	ß-glucuronidase
HPLC	High Pressure Liquid Chromatography
HR-ICPMS	High Resolution Inductively Coupled Plasma Mass Spectrometry
ICPMS	Inductively Coupled Plasma Mass Spectrometry
IGER	Institute of Grassland and Environmental Research
LAS	Linear Alkyl benzene Sulfonates
MAST	Marine Science and Technology Programme (under CEC)
MIT	Mineralization-Immobilization Turnover
MTBE	Methyl t-butyl ether
NORN	Nordic Project on Nitrogen in Arable and Forest Soils
N-PAC	Nitrated Polycyclic Aromatic Compounds
N-PAH	Nitrated Polycyclic Aromatic Hydrocarbons
NPL	National Physical Laboratory
PAC	Polycyclic Aromatic Compounds
PAH	Polycyclic Aromatic Hydrocarbons
PCR	Polymerase Chain Reaction
POM	Polycyclic Organic Matter
RAPD	Random Amplified Polymorphic DNA Technique
RERAF	Risø Ecological Risk Assessment Facility
RFLP	Restriction Fragment Length Polymorphism
RIMI	Risø Integrated Environmental Project
RP-HPLC	Reverse Phase High Performance Liquid Chromatography
RVAU	The Royal Veterinary and Agricultural University
RVP	Reid Vapour Pressure
TLC	Thin Layer Chromatography
TOR	Tropospheric Ozone Research
VOC	Volatile Organic Compounds

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Title and authors

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Pages	Tables	Illustrations	References
44	3	4	

Abstract

The purpose of the annual report from the Plant Biology and Biogeochemistry Department (previously The Environmental Science and Technology Department) is to provide a summary of our research and achievements and to give an idea of the research directions in the Department.
The Department is engaged in research to establish the scientific basis for new methods in industrial and agricultural production.Through basic and applied experimental research, the Department aspires to develop methods and technology for industrial and agricultural production, exerting less stress and strain on the environment. The research approach in the Department is mainly experimental.
Selected departmental research activities during 1997 are introduced and reviewed in seven chapters: 1. Introduction, 2. Atmospheric Chemistry and Air Pollution, 3. Resistance Biology and Plant Genetics, 4. Plant-Microbe Symbioses, 5. Plant Ecosystems and Nutrient Cycling, 6. Trace Elements and Organic Matter, 7. Dosimetry and Industrial Irradiation.
The Department's contribution to education and training are presented. Lists of publications, lectures and poster presentations at international meetings are included in the report. The names of the scientific and technical staff members, visiting scientists, Postdoctoral fellows, Ph.D. students, M.Sc. students and apprentices are also listed.

Descriptors INIS/EDB

Available on request from Information Service Department, Risø National Laboratory,
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RISØ

Risø National Laboratory carries out research within science and technology, providing Danish society with new opportunities for technological development. The research aims at strengthening Danish industry and reducing the adverse impact on the environment of the industrial, energy and agricultural sectors.

Risø advises government bodies on nuclear affairs.

This research is part of a range of Danish and international research programmes and similar collaborative ventures. The main emphasis is on basic research and participation in strategic collaborative research ventures and market driven tasks.

Research is carried out within the following programme areas:

- **Industrial materials**
- **New functional materials**
- **Optics and sensor systems**
- **Plant production and circulation of matter**
- **Systems analysis**
- **Wind energy and atmospheric processes**
- **Nuclear safety**

Universities, research institutes, institutes of technology and businesses are important research partners to Risø.

A strong emphasis is placed on the education of young researchers through Ph.D. and post-doctoral programmes.

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Risø reports its activities in 1997 in the following ten publications: Risø Annual Report, Risø Business Statement (only available in Danish), Risø Publication Activities and the annual progress reports of the seven research departments. The publications and further information on Risø is available from the web site www.risoe.dk. Printed copies of the reports are available from the Information Service Department, phone +45 4677 4004, email risoe@risoe.dk, fax +45 4677 4013.